THE ELECTRIFICATION OF RAILWAY TERMINALS

A REPORT PREPARED UNDER THE AUSPICES OF THE MAYOR AND COMMITTEE ON LOCAL TRANSPORTATION OF THE CITY COUNCIL

CHICAGO
R. R. DONNELLEY & SONS COMPANY
1908

Courtesy General Electric Co

New York Central & Hudson River Railroad — Electric Locomotive, with Train Running at Sixty Miles per Hour.

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THE ELECTRIFICATION OF RAILWAY TERMINALS

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AS A CURE FOR THE LOCOMOTIVE SMOKE EVIL IN CHICAGO WITH SPECIAL CONSIDERATION OF THE ILLINOIS CENTRAL RAILROAD

PREPARED UNDER THE AUSPICES OF THE MAYOR AND
Chicago COMMITTEE ON LOCAL TRANSPORTATION
OF THE CITY COUNCIL

BY

MILTON J. FOREMAN
CHAIRMAN, COMMITTEE ON LOCAL TRANSPORTATION, CITY COUNCIL

WILLIAM A. EVANS
COMMISSIONER OF HEALTH

PAUL P. BIRD
SMOKE INSPECTOR

GILBERT E. RYDER
SMOKE INSPECTION DEPARTMENT

HERBERT H. EVANS
MECHANICAL ENGINEER

CHICAGO
R. R. DONNELLEY & SONS COMPANY
1908

FRED A. BUSSE, Mayor.

COMMITTEE ON LOCAL TRANSPORTATION OF THE CITY COUNCIL OF THE CITY OF CHICAGO.

Milton J. Foreman, Chairman,

John W. McNeal,	Nicholas R. Finn,
Linn H. Young,	Charles M. Foell,
Dennis J. Egan,	Winfield P. Dunn,
Michael Zimmer,	Peter Reinberg,
William E. Dever,	Henry J. Siewert,
John P. Stewart,	Ernest Bihl.

ELECTRIFICATION OF RAILWAY TERMINALS

To The Mayor and The Committee on Local Transportation of The City Council, City of Chicago, 1908.

The Honorables Fred A. Busse, Mayor, Milton J. Foreman, Chairman, John W. McNeal, Linn H. Young, Dennis J. Egan, Michael Zimmer, William E. Dever, John P. Stewart, Nicholas R. Finn, Charles M. Foell, Winfield P. Dunn, Peter Reinberg, Henry J. Siewert, Ernest Bihl.

Gentlemen:

In obedience to your request, we have investigated the question of electrification of railroads. The questions that we have tried to determine are:

1. Does the smoke from the present method of locomotive traction do harm, and if so, how much?

2. Would the substitution of electric traction within the city of Chicago rectify this condition?

3. Has electric traction developed to the point where it has demonstrated its availability?

4. Would electrification of the terminal zones be a reasonable demand on the railroads?

This point being duly weighed, resolves itself into two sub-questions: (*a*) Is electric operation physically feasible? (*b*) Are the financial situations such as to make it feasible?

The major portion of our study has been on the fourth of these questions, and especially on division (*a*) thereof. This, in turn, divides itself into three questions: suburban passenger, through passenger, and freight business. The advantage from handling the first of these by electricity is generally conceded. The second is probably proven. Most of our study is on the third of these, — relatively the greatest nuisance of the three, and the one to which least thought has been given.

We understand that it is not our function to suggest plans or to specify details except in so far as they are necessary to get a clear comprehension of the business. Only such details will be set forth in our report as are necessary for a judicial consideration by the reader of the points made in the paper.

We understand that many roads have already studied the problem. Before any railroad electrifies, it will make many studies not only on their problems, but on those of the general proposition. Furthermore, each year's experience will tend to solve some of the remaining problems. It would be fairer to try the question of electrification by the standards of immediate reasonable expectation than by the practice of, say, three years ago. Each of these points of view we have tried to avoid, though the influence of each will be in some measure apparent.

In our judgment, it has seemed best to study one concrete situation rather than a more generalized survey. While the problems of the roads differ, the basic principles are the same. If electrification is found to be fundamentally feasible in the case of one road, it will only require adaptation to fit the conclusions to any road.

The Illinois Central has been selected as the basis of this study. The reasons for this are twofold: First, the railroad comes into the very best part of town. It occupies much of the lake front. It is in the midst of a park and boulevard system which it at present greatly harms, and for the construction and maintenance of which the people have spent large sums of money and plan to spend very much more. Second, when these studies were taking shape, President Harahan wrote the following letter, replying to one from Mr. Henry Morris of the Hamilton Club:

ILLINOIS CENTRAL RAILROAD COMPANY
OFFICE OF THE PRESIDENT

CHICAGO, April 4, 1908.

MR. HENRY C. MORRIS,
Chairman Committee on Municipal Art and Civic Improvement, the Hamilton Club, Chicago.

My dear Sir,— Replying to your letter of April 3d, with reference to the topics undertaken by your committee, and referred to in your pamphlet as items 1, 2, 3, 4, and 20, I beg to reply as follows:

With regard to the substitution of electric power for steam on locomotives, would say that it is a very large question, and one which cannot be answered off-hand. The electrification of steam railroads as far as pertains to the handling of business outside of cities is a simple question, but when it comes to the electrification of large terminals like those of the railways of Chicago, it is an entirely different question.

The experience in the electrification of the New York Central terminals in New York City has developed many difficulties, one of the greatest of which is a financial one. It is apparent to any business man that he cannot afford to make a large initial outlay unless such outlay is compensated by a reduction in the cost of operation. The exact contrary has been the experience with reference to the New York Central terminals in New York City. This, coupled with the fact that the present time is not an opportune one for making large expenditures, will necessarily postpone the matter of electrification of large terminals like those of the railways of Chicago.

The art of electrification of steam railroads is yet in its infancy and the experience has not been sufficient to demonstrate the most economical type. There is no question, however, that with the advancement of the art the future will see a large development in the electrification of existing steam roads. It is not possible, however, in any business to set aside the present plant, in which these is a large investment, and make a further large initial expenditure to provide an entirely new equipment. I think it must be recognized as an economic fact that large outlays of money cannot be made without compensating returns.

With reference to the abatement of the smoke nuisance, it has been our purpose in the past, and will be in the future, to co-operate with every movement that tends toward the suppression of this element, and we are constantly on the alert, training our men and disciplining them in the correct method of using coal on our locomotives. The fault, however, does not entirely lie with the railroads. If you will observe the volumes of smoke made by factories and vessels entering Chicago harbor, I think you will reach the conclusion that even with the elimination of the smoke nuisance by steam locomotives, only a very small part of this nuisance will have been abated.

With reference to suppression of unnecessary noise, it is a rule with us that no unnecessary noise shall be made by locomotives on our terminals.

Regarding the promotion of a higher degree of public spirit on the part of railroad companies in the better maintenance of conditions around passenger and freight terminals, beg to say that we are in hearty accord with such a movement, and are making an earnest endeavor to promote these conditions.

I think the work undertaken in your Civic Programme is a most commendable one, and merits the hearty co-operation of manufacturing, industrial, and transportation interests of Chicago.

Yours truly,

J. T. Harahan,

President.

This so clearly expressed the situation just as we saw it, it specified so exactly the need for just the study that we were making, that we decided to make the Illinois Central the particular problem to be studied. What we find to be true of them can be and will be adapted to each of the roads entering the city.

If it will pay them to electrify then it will pay the others; if they are doing harm by smoke and therefore should electrify, then should the others.

Furthermore the roads occupying one railroad station, generally speaking, use much track and many other commodities in common. It will not represent the highest economy of operation or of upkeep to have one road electrified and another not. Therefore, practically, the matter will work out by the consideration of all the roads entering one station as a unit. Into the Illinois Central station the Michigan Central, the Big Four, and the Wisconsin Central run. The Michigan Central has a trackage arrangement. Economy would demand that the Michigan Central adopt electric traction not only on the Illinois Central tracks from Kensington in, but also to Hammond, or maybe beyond before many years. The Big Four has a wheelage contract and will therefore be served by the same traction arrangements as the Illinois Central. The Wisconsin Central has a trackage agreement from Harlem Junction in, and should pursue the same general policy as the Illinois Central. The few thousand feet of track called the St. Charles Air Line, and owned by the Illinois Central and three other lines would probably be used for a while for both electric and locomotive traction. The Chicago, Cincinnati, and Louisville will be treated as the Michigan Central. The Kensington and Eastern is already electrified east of Kensington.

Certainly with this group, and probably with each group, group treatment will be the most practicable.

The different subjects to which we have addressed our inquiries appear as the subject heads, and are as follows:

The Harm of Smoke. W. A. Evans.

The Prevention of Smoke in Chicago. Paul P. Bird.

The Railroads as Smoke Producers. G. E. Ryder.

The Possibility of Smokeless Steam Locomotive Traction. G. E. Ryder.

Anthracite Coal and Coke as Remedies. Paul P. Bird

Electrification as a Remedy with Special Consideration of the Illinois Central. H. H. Evans.

- A. The General Aspects of Electrification.
- B. Systems Available for Electrification.
- C. Existent Installations of Electrical Traction.
- D. The Electric Handling of Freight.
- E. Notes on Economics.
- F. The Situation in Chicago.
  - (*a*) General.
  - (*b*) The Illinois Central.
    - 1. Through passenger.

2. Suburban passenger.
3. Freight.
4. Probable cost and results of the electrification of this terminal.

The Railroads in Relation to Local Transportation. Milton J. Foreman.

Conclusions. Milton J. Foreman, W. A. Evans, P. P. Bird, G. E. Ryder, H. H. Evans.

Addenda. Charts and Computations. P. P. Bird, G. E. Ryder, H. H. Evans.

As these chapters are written by different people and as the same subject is sometimes considered by the same writer from a somewhat different viewpoint, some duplication will be found. Such duplications we have chosen to leave, as they seem necessary in the places where they appear.

The results of these studies we respectfully submit.

Signed,

Milton J. Foreman,
Chairman Committee on Local Transportation, City Council.

W. A. Evans,
Commissioner of Health.

Paul P. Bird,
Smoke Inspector.

G. E. Ryder,
Smoke Inspection Department.

H. H. Evans.

ACKNOWLEDGMENTS

The material and information contained in this report and the additional information and ideas upon the whole of which we have based our conclusions have come to us from a number of sources. We wish to thank the contributors thereto for the uniform kindness and obligations with which we have met in our investigation.

In making this study several visits were made to electric-traction plants in operation. In July, 1907, Mayor Busse, Comptroller Wilson, Alderman Foreman, Mr. Donnelley, and Dr. Evans inspected the New York Central plant and were shown the workings of the system by Vice-President Wilgus. In October, Mr. Bird attended the discussion of Mr. Wilgus's paper before the American Society of Civil Engineers. On the same date, Dr. Evans attended the lecture by Mr. Armstrong before the Western Section American Institute of Electrical Engineers. In June, 1908, Dr. Evans, Mr. H. H. Evans, and Mr. G. E. Ryder visited the following places, studying electrical traction: International Traction Co., Niagara Falls, N. Y.; General Electric Co., Schenectady, N. Y.; New York Central terminal, in and near New York; the various power-plants in and near New York of the local traction or lighting companies; New York, New Haven & Hartford electrification, Woodlawn, N. Y., to Stamford, Conn.; Long Island railroad; Baltimore & Ohio electrification, Baltimore; Washington, Baltimore & Annapolis, Baltimore to Annapolis; Baltimore & Annapolis Short Line; Westinghouse plants at Pittsburg; Allis Chalmers Company plants at Milwaukee; Grand Trunk electrification at Port Huron, Mich.; Michigan Central tunnel at Detroit, Mich,; University of Illinois, Urbana, Illinois; Aurora, Elgin, & Chicago electric railway; street car and elevated lines in Chicago and those of the Illinois Traction Company.

We are glad to acknowledge valuable information and help from the following sources:

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Mr. F. J. Sprague, New York City.

Mr. L. B. Stilwell, New York City.

Mr. W. J. Wilgus, New York City.

Mr. L. S. Wells, Long Island railroad.

Mr. Egan of the Grand Trunk railroad.

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Mr. L. A. Lamb of "At the Market."

Mr. C. L. Furey of the American Guarantee Co.

The detail engineering work has been done by the staff of the Smoke Inspection Department.

We have made free use of the following literature:

Transactions American Society Civil Engineers.

Transactions American Institute Electrical Engineers.

Transactions American Society Mechanical Engineers.

Journal American Society Naval Engineers.

Journal Institute of Civil Engineers.

Journal Institution of Electrical Engineers.

Proceedings Western Society of Engineers.

Proceedings New York Railway Club.

Journal Royal Sanitary Institute.

Journal American Medical Association.

Boston Medical & Surgical Journal.

The Electrification of the Suburban Zone of the New York Central. W. J. Wilgus.

On the Substitution of the Electric Motor for the Steam Locomotive. L. B. Stilwell.

Some Facts and Problems bearing upon Electric Trunk Line Operation. F. J. Sprague.

Various contributions to the technical press in recent years of Messrs. Lamme, Mailloux, De Muralt, Sprague, Stilwell, Brinckerhoff, Arnold, Wilgus, White, Street, Lyford, Gibbs, Arnold, Armstrong, and Potter.

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Der elektrische Betrieb mittels Dreiphasen. Drehstrom auf den italienischen Vollbahnlinien in Valtellina. Köhn.
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Economics of Railway Operation. Byers.
Notes on Electric Railway Economics. Gotshall.
Historical Sketch of the Illinois Central. Ackerman.
Standard Handbook for Electrical Engineers.
Electrical Engineers' Pocket Book. Foster.
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American Street Railway Investments, 1907.
Stone & Webster. Electric Railway & Lighting Properties.
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THE HARM OF SMOKE

W. A. EVANS

The disadvantages of smoke are easy to demonstrate in so far as it ruins unwashable clothes and dirties washable clothes and greatly harms properties such as buildings and other things which are not easily cleaned.

The money cost from smoke is a very large item. Says C. A. L. Reed, in addressing the Women's Clubs of Cincinnati, Ohio (American Medicine, April 25, 1905):

"But martyrs as are women to the smoke nuisance, there are other interests that are equally violated by its existence and perpetuation. Thus it would be interesting to know if it were possible to ascertain how many thousands of dollars' worth of merchandise is annually lost by our dry-goods merchants, solely through the ravages of smoke and soot. Clothiers, milliners, dressmakers, tailors, outfitters, grocers, druggists, are singularly subject to damage from the same cause. Jewelers are put to extra labor and expense to protect their wares, especially silver-plate, against the influence of corroding gases that impregnate the atmosphere as the result of imperfect combustion in numerous manufacturing establishments. The damage that has been done and is being done to residence property in Cincinnati and other cities similarly enshrouded with smoke is beyond computation. And the worst of it is that the inhabitants who have fled from their homes, many of them elegant and even palatial establishments, leaving them at a great loss to the ravages of smoke, are followed by the same pest that, presumably in the interest of the manufacturer, now threatens to make our suburbs as untenantable as our downtown districts. There is, in fact, not a single branch of the mercantile business, there is no private property interest that is not forced in this way to pay tribute to what I am convinced are totally unnecessary conditions imposed upon our great urban communities by the manufacturing interests that are, in fact, not in the least advanced by these same conditions. I am reliably informed that, quite to the contrary, these same manufacturers who thus insist upon defiling our cities, sacrifice from 15% to 25% of their fuel to accomplish the purpose — not deliberately, perhaps — not maliciously, certainly, — but ignorantly, or at least thoughtlessly. For, as Dr. Ohage, the able health commissioner of St. Paul, recently remarked, 'Smoke is not a mark of industrial activity, but of industrial stupidity.' "

In speaking of the pollution of the air by smoke, Reed quotes the President as saying:

"It would seem to be wise to go to the very limit of the law, and to arrest the member of the company, or those highest up in the company, again and again with the shortest possible intervals, in order to put a stop to this nuisance that, so conducted on their part, amounts to a flagrant defiance of the law, and respect for public opinion."

The Syracuse Commission quotes from the Cleveland Committee's report as follows:

"The presence of coal smoke in large quantities constitutes perhaps the greatest hindrance to the highest development of civic beauty and refinement. Its effect is seen in all plant life. The growth of green conifers is almost impossible, and only hardy and smooth-leaved trees are comparatively unaffected.

"No definite estimate has been made of the amount of loss of vegetation resulting directly from the presence of smoke and gas in the air, but the St. Louis Forestry Department figures conservatively an annual loss of 4 per cent, and these figures may doubtless be assumed for Cleveland. Ordinarily, flowering plants wither and die in smoky districts unless given especial care.

"To a considerable extent the architectural effects of our buildings are destroyed by damage from this source. Buildings of almost every material are in a few years brought to a common level — a grimy hue which robs them of their distinction. It is only through constant treatment by special process that stone buildings can be restored to their original color, and this process is frequently harmful to the surface and durability of the stone. Painted buildings in a short time lose their color because of the coating of soot and the effect of chemical gases. Prevailing conditions make impossible the successful use of lighter or more cheerful colors without constant and expensive renewal.

"It is difficult to estimate the effect upon health of any considerable quantity of smoke and gas in the air. It is known, however, that it acts as an irritant to the lungs and throat and nasal passages; that it is one of the pre-disposing causes of disease in these organs, and that it aggravates any existing disease. An inspection of the screens which are used in hospitals to purify the air drawn through the ventilating system shows, after twenty-four hours, astonishing results which are more eloquent than any description can be.

"The most tangible results from the smoke nuisance can be shown, perhaps, in the financial loss to the community. It is, of course, impossible to set forth anything like the total loss. A few carefully compiled estimates, however, from actual experience, will suffice to indicate something of its magnitude. There are approximately four hundred retail dry-goods stores in Cleveland doing a business of from $10,000 to $3,000,000 or $4,000,000 a year. The owners of some of these stores estimate (and the same estimate is given in other cities) that of all white goods sold a clear loss of at least 10 per cent must be figured. Taking the single items of underwear, shirt waists, linens, and white dress goods, for the eleven department stores, the proprietors conservatively estimate their combined loss at $25,000. Consider, then, the loss in all lines of light goods for all four hundred stores. The wholesale dry-goods houses show a similar loss. There are in Cleveland fifty-five men's furnishing stores, and the conservative estimate of loss to these stores is placed at $15,000 annually. It is a simple matter to distinguish between the soil from ordinary dust and that due to the presence of coal smoke and gas. The former is easily removed; the other, due to an air saturated with smoke, is absorbed, rendering the fabric practically beyond redemption, from the standpoint of the salesman. The stores mentioned represent only a small proportion of the trade directly affected. One hundred and fifteen tailors, twenty-nine cloak and suit manufacturers, forty-nine millinery establishments, eighteen hat and coat stores, thirteen skirt manufacturers, three collar and cuff manufacturers, and many other trades are affected in a similar degree. Aside from the damage to stock, an annual cost for cleaning, particularly among retail houses, must be included. Some conception of this loss may be had from a single instance. One retail establishment paid in just a year after the painting and decorating of its walls and ceilings, $1,800, for repainting and redecorating, made necessary entirely by the effect of smoke. During the same year their bill for window cleaning was $2,000; for laundry purposes $1,500. This, in a large measure was due to the smoke nuisance. Multiply their figures by the thousands of business houses needing the same attention, in greater or less degree, and some estimate of the total cost in this direction may be obtained. To this should be added the cost of lighting, particularly in retail stores, factories and offices, made necessary by the smoky atmosphere. Some of the larger houses charge several hundred dollars to this account.

"But a greater cost than all of these must be considered in the loss to the one hundred thousand homes of Cleveland. The constant need of cleaning of walls, ceilings, windows, carpets, rugs, and draperies; for redecorating and renewing, can only be realized by the house-owner or housekeeper. To this add the increased laundry bills for household linen, the dry cleaning of clothing, and the great additional wear resulting from this constant renovation. Consider also the permanent injury to books, pictures and similar articles. Though impossible of computation, it will be seen that the total of these items aggregates millions of dollars. The annual tribute which Cleveland must pay to the smoke nuisance is a sum sufficient in a single year to equip all plants, not so provided, with smoke-preventing devices."

The Syracuse Commission says: "These statements apply to Syracuse as well as to Cleveland, due allowance being made for the difference in size of the two cities, and for the fact that the Ohio coals are in general smokier and dirtier than those used in our city."

When 2¼ millions of people are gathered, working and living, on 195 square miles, some acres housing as many as three hundred at night, and many housing more than 1000 in the day, something is required to maintain the chemical equilibrium of the air.

The three considerable factors in this are the air which serves to dilute, the waters which absorb, and the vegetation which transforms. Fortunately for Chicago, we have winds during most every hour of most every day. Again, fortunately for us, Lake Michigan serves to purify our air much of the time. It is unfortunate that a good part of the air which comes over the water to the shore is polluted before it becomes available for the use of the people by the smoke of railroads and industrial plants located on the lake front.

The country which surrounds Chicago is not as advantageous from the standpoint of vegetation as could be desired. It is relatively free from trees and other forms of vegetation. There is, therefore, the greater need of trees and vegetation within the city. Our streets are poorly shaded. The trees along the boulevards are runty. The small squares and parks have none. The reasons for these shortcomings are several:

1. Much of the ground is covered by roofs and paving, and is drained by sewers, so that the soil is dry.
2. The soil is packed.
3. It is poor.
4. The air is so charged with harmful gases that vegetation cannot grow.

For example, in Grant Park, where heavy wooding is so greatly needed to maintain atmospheric equilibrium, there is so much air pollution that trees do not thrive.

Unfortunately, the coals which have been so cheap as to greatly make for our financial gains, run high in volatile matter and in consequence make smoke which is especially harmful to vegetation.

Trees and grass grow imperfectly in the vicinity of smoke-producing factories and railroads. Especially is this true of plants with shaggy leaves. Members of the pine and fir families will not grow, neither will evergreens. Superintendent Foster writes me that they have never succeeded in getting trees to live in Grant Park. This they attribute to the Illinois Central smoke.

The citizens of Chicago have spent large sums of money in a general park scheme of which foliage in Grant Park is a constituent part. This, however, is less important than the health necessity of trees for the thick populations adjacent to this park.

Agar (Journal Royal Sanitary Institute, 1907, Volume 27) says that in London shrubs rarely break (or sprout) from below on account of the incrustation of smoke. Riggs' testimony, in the same journal, is to the same effect.

An excellent consideration of the smoke question is to be found in this journal. Riggs says that many plants can be made to live if they are systematically washed. If you will examine the leaves of the trees at present in Grant Park, you will see that they are covered with soot and tar.

The use of coke lessens the amount of soot but it may even make the sulphur gases more harmful, as they are not easily seen. The dust from 20 sq. yards of an exposed glass surface at Kew showed 5% sulphuric acid — 2% sulphur.

Rideal found that London air in clean, breezy weather contained .015 grams of sulphurous acid per 100 cu. ft. of air. In foggy weather it rose to 0.51 and 0.77 grams per 100 cu. ft. of London and Manchester air. This accumulation of sulphurous and sulphuric acid poisons plants and men to some degree. Riggs says that a London garden costs twice as much as a country garden because of the cost of washing the plants. Soil for the plants should have a lime dressing to absorb the sulphur. Rideal has found that whitewashed walls were very serviceable in absorbing from the air the sulphur gases contained in the smoke.

Markel says that the greatest harm which is done by the sulphur gases is done to metal structures. This, he says, is not in direct proportion to the amount of sulphur in the air. His explanation is as follows: Sulphurous acid falls on iron and is at once oxidized into sulphuric acid. It corrodes the iron and makes ferrous sulphate. This then picks up oxygen from the air and makes basic ferric sulphate, which in turn picks up iron and makes ferrous sulphate and iron oxide. The iron oxide is sloughed as rust and the ferrous sulphate starts a new cycle. Thus it is back and forth, picking up iron from the structure and oxygen from the air. The sulphur bounding back and forth eats up the metal as a bacterium or a ferment would do with an organized chemical compound. This is a most interesting scientific explanation of why metal exposed to smoke which contains sulphur gases melts away like cloth which is moth eaten.

The harm which smoke does to wooden structures acts largely through its paint or whitewash. The major consequence is in the greater cost of maintaining a pleasing appearance. Whitewashed houses will absorb a great deal of SO_2 from the air, purifying the latter. This forms a gypsum on the surface of the wood and therefore loses its value as a whitewash.

Stone and brick houses are discolored and made dull and dreary by smoke. Those building materials formed largely of silicates are not otherwise harmed. The softer limestones under the influence of CO_2 and SO_2 will shale and lose both finish and crushing strength in time.

The harm done vegetation from smoke proceeds from several sources. The pores of the leaves are filled by the particles of insoluble carbon. The trees are poisoned by carbon monoxide gas. They are also poisoned by this tarry oil.

Thistleton Dyer says that 6 tons of solid matter consisting of soot and tarry matter are deposited every week on every 160 acres in and around London. This is about 3,966 pounds per acre per year.

In Glasgow this was 2,211 to 2,564 pounds per acre per year. It consisted of carbon, carbon compounds, sulphur compounds, organic matter not soluble in ether, and ether-soluble hydrocarbons.

Schafer (Boston Medical and Surgical Journal, July 25, 1907,) says that London burns 30,000 tons of coal a day and that this pours 300 tons of soot and 100,000 tons of CO_2 into the air. That about 3% of coal is sulphur and that this is poured into the air as SO_2 and speedily becomes sulphuric acid. In Glasgow and in Manchester 20 tons of sulphurous acid are poured into the air each day. When the pollution of the air by sulphuric acid reaches 1 part in 1,000,000 vegetation suffers intensely.

Cohen says that in Leeds .5 to 5% of all coal burned goes into the air as soot and 15% of this soot is a sticky mineral oil. This oil is destructive to vegetation and also dirties clothes and may be a factor in ruining them.

In addition to this tarry matter, smoke is rich in sulphur gases. Cohen and Hefford say that of 100 lbs. of sulphur in coal 71.78 lbs. will go off as sulphur gases; 14.51 lbs. will be absorbed into the soot and escape with it; 13.71 lbs. will remain in the ash. In London each day the smoke carries off sulphur from coal 981,792 lbs.; sulphur from gas 893 lbs.; sulphur from mineral oils 743 lbs.

A large item of cost from the smoke evil is the increased expense of lighting. The St. James Gazette, Oct. 14, 1903, said that smoke cost London $35,000 a day for extra light.

Probably more important still is the effect of smoke on health. Jacobi does not agree with the editorials in the Journal American Medical Association, May 20, 1905, July 6, 1906, and August 4, 1906. He says that we should drop the idea that the smoke question is only social and not medical.

It is, however, difficult to trace disease to air pollution with enough of certainty to secure more than a Scotch verdict of "guilty but not proven."

Says a writer in the Journal of the Royal Sanitary Institute, 1907: "During the winter of fog of '79–'80, the deaths were several thousand above normal. During the 100-hour fogs the London deaths were 1,442 above normal."

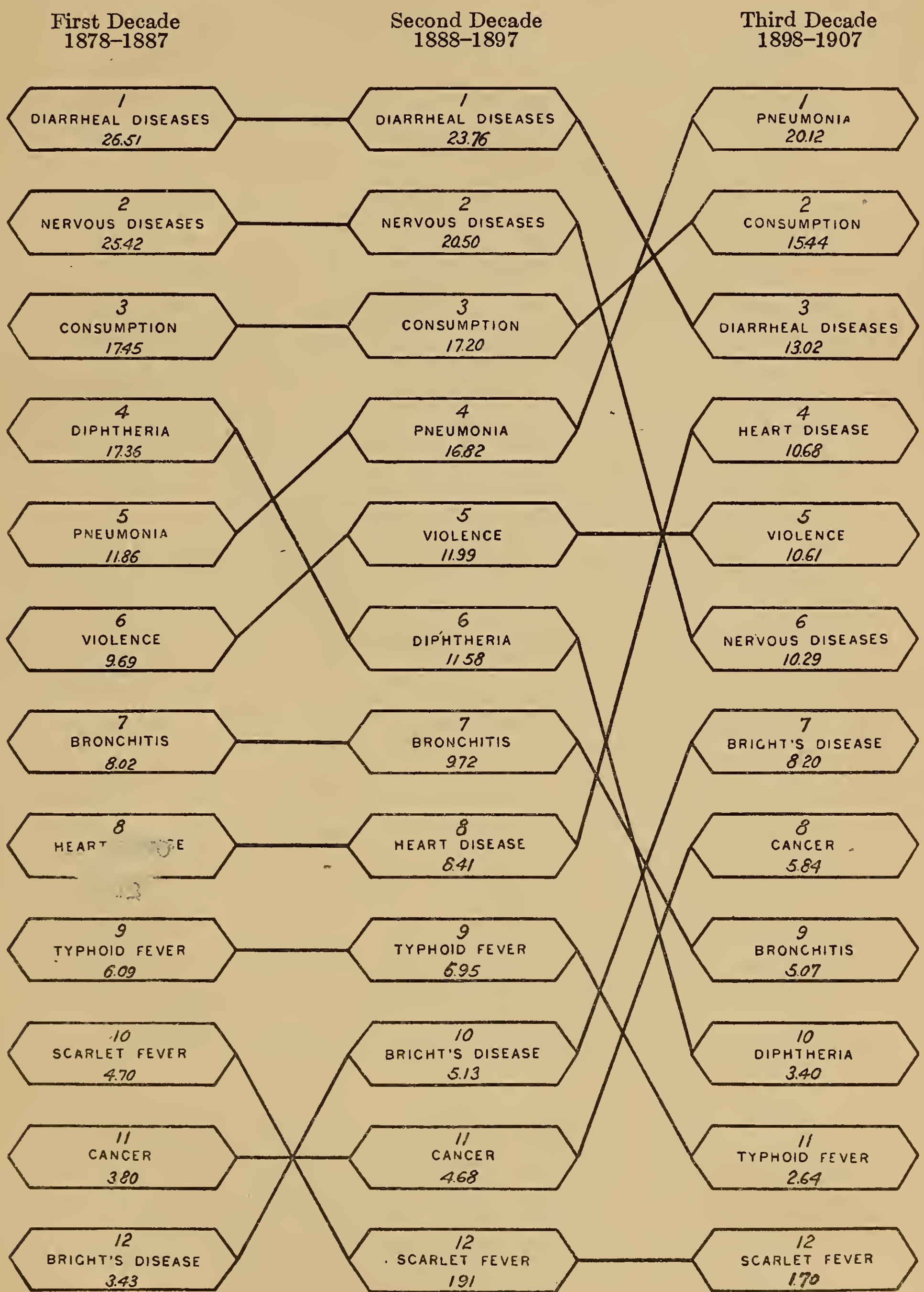
According to the reports of the U. S. Department of Commerce and Labor the mortality from pneumonia is 50% higher in the dirtier-aired cities as compared with the country. Archer f[illegible] that if two animals were infected with tuberculosis and one was [illegible]ven good air and another smoky air, the animal breathing smoky air would die more quickly than the other. If two animals were taken; one was allowed to breathe good air and the second was allowed air containing a small quantity of smoke — if, now, both animals breathed aspergillus spores, the one which had inhaled smoke would get pneumonia, the other would not.

In the Philadelphia symposium, the only remedy offered for a condition recognized as needing remedy was that of Leffman who advised anthracite and coke within the city limits.

May not the increased death rate of the winter months as compared with the summer be due to the better ventilation and greater air dilution of the summer? In Chicago during January, February, March, April, May, and December of 1907, 18,008 people died as compared with 14,135 for the remaining months.

TWELVE CHIEF CAUSES OF DEATH IN CHICAGO

Shown in order of highest rates by decades. Deaths per 10,000 population in each decade, 1875–1907.



There has been a progressive decrease in the death rate in the last fifty years. As the chart shows, the Chicago rate has fallen from 27.56 per thousand in 1857 to 14.18 in 1906 and 15.25 in 1907. Better drainage has wholly eliminated malaria and cholera and has contributed to the material decrease in typhoid fever and the practical elimination of dysentery.

Better water has reduced typhoid fever from 17.28 per 10,000 (the maximum in 1891) to 1.78 in 1907. Better food has eliminated diarrhœal disease in adults. Better control has reduced smallpox from a maximum of 23.04 in 1882 to 0 during the current year. Diarrhœa in babies has come down from 64.84 in 1857 to 13.26 in 1906 and 13.31 in 1907. Infant mortality from 100.4 in 1868 to 29.8 in 1906. Diphtheria, scarlet fever, measles, whooping cough, smallpox, typhoid fever, and erysipelas from 45.19 in 1851 to 26.07 in 1888; to 10.165 in 1907. As we run down the records of vital statistics we come to expect that everywhere in preventable disease improvement will be found. This expectation is not fulfilled. During the same period there has been but little recognition of the relation of bad air to disease.

Pneumonia, bronchitis and consumption, forming the group of bad-air diseases, are not improving. They exact a heavier toll year by year. Reference to the charts and tables shows such items as a death rate from these diseases of 31.71 in the decade 1858 to 1867, and 40.63 in that from 1898 to 1907. The general death rate in 1858–67 was 23.54; in 1898 to 1907, 145.6.

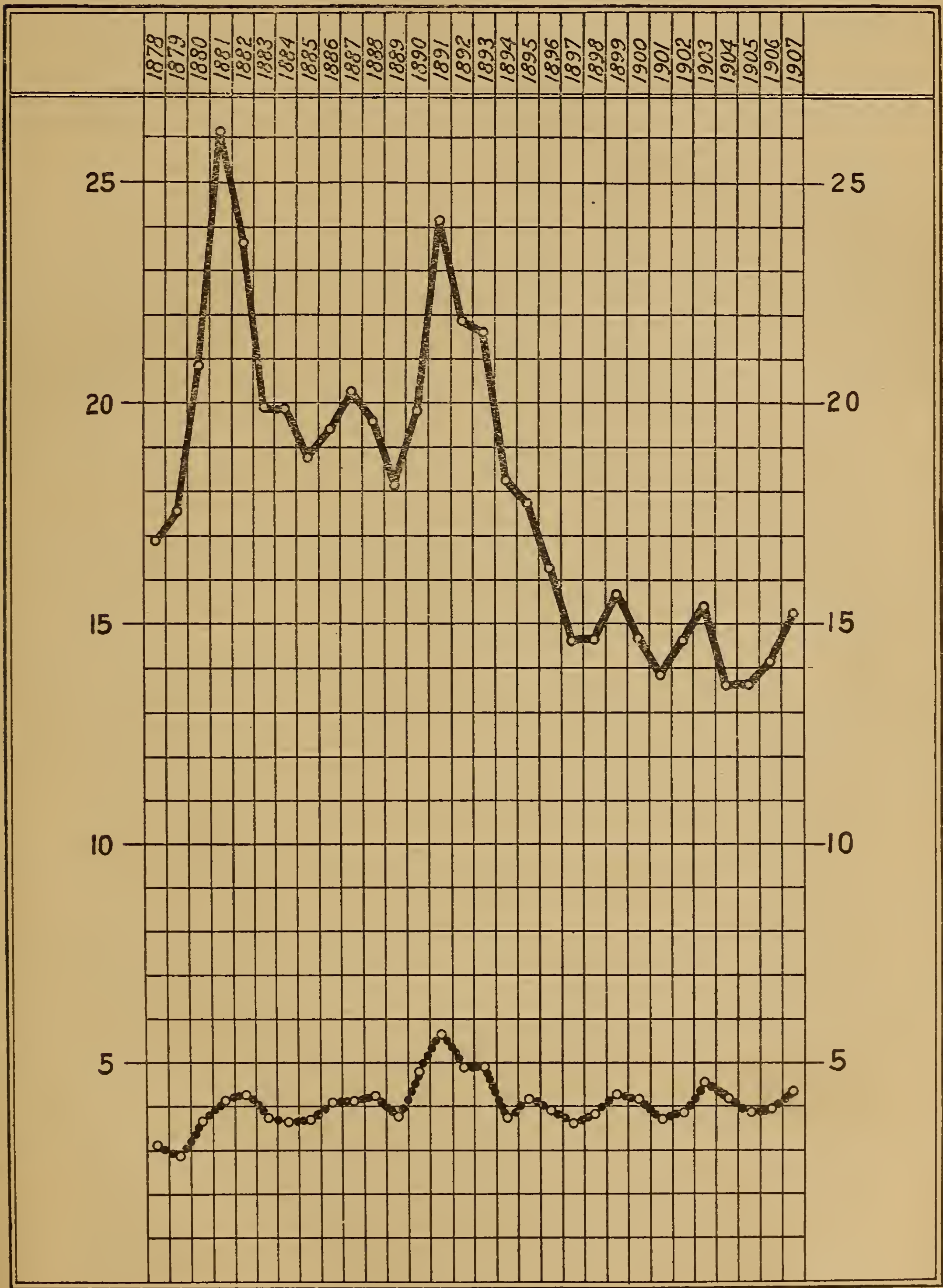
We have spent millions to raise the city level and bring about drainage and eliminate swamps. We have purified our water. We do not suffer our soil to be polluted by manure or other excretions. We force a standard of foods on farmers, butchers, and all food-producers. These exactions have borne fruit. Why is it that we allow the air, so much more important than any of these, to be polluted without let or hindrance? Do not these figures prove a health necessity for control of air?

It is difficult for 300 men to live on an acre in peace and health. To do it they need vegetation and sunlight. They pay for the privilege of living crowded. They pay in restrictions on water, on sewage, on waste. They pay with the sacrifice of their liberties and rights. Shall not others pay?

Says Reed: "Then, too, there is something to be said about the ethics of the air. Air is necessary to existence. This being true, to breathe pure air must be reckoned among man's inalienable rights. No man has any

DIAGRAM SHOWING DEATH RATES

From all causes and the impure air diseases during the last thirty years, 1878–1907. Deaths per 1,000 population by years. All causes, upper line; impure air diseases, lower line.



more right to contaminate the air we breathe than he has to defile the water we drink. No man has any more moral right to throw soot into our parlors than he has to dump ashes into our bedrooms. No man has any more right to vitiate the air that sustains us than he has to adulterate the food that nourishes us. Poison taken into the body through the lungs is just as much a poison as is some other poison swallowed into the stomach. Poisonous air is probably more disastrous to infants than is adulterated milk. A man's proprietorship extends as distinctly into the air above him as into the earth beneath him. If every man is entitled to the ground he stands upon, so is he entitled to the air that envelops him."

If the people have spent their money by hundreds of millions by taxation for canals and sewers and have spent other millions to raise the city above datum in order that they might be healthy; if the statistics prove that these expenditures have returned lives, health and earning power enough to justify them; if the figures show that air pollution is now doing more harm than any other agency of economic waste, have they not the right to ask that those who pollute the air spend some money to prevent that pollution?

This postulate can be maintained. Government must keep pure air and water and all other things used in common by the people, and to this end they have all needed powers.

Not all of the lung and throat disease is due to dirt in the air. Not all of the dirt is due to smoke. Not all the smoke is due to locomotive engines. But engines are large contributors to a large factor in the three most important diseases in the world, consumption, pneumonia, and bronchitis.

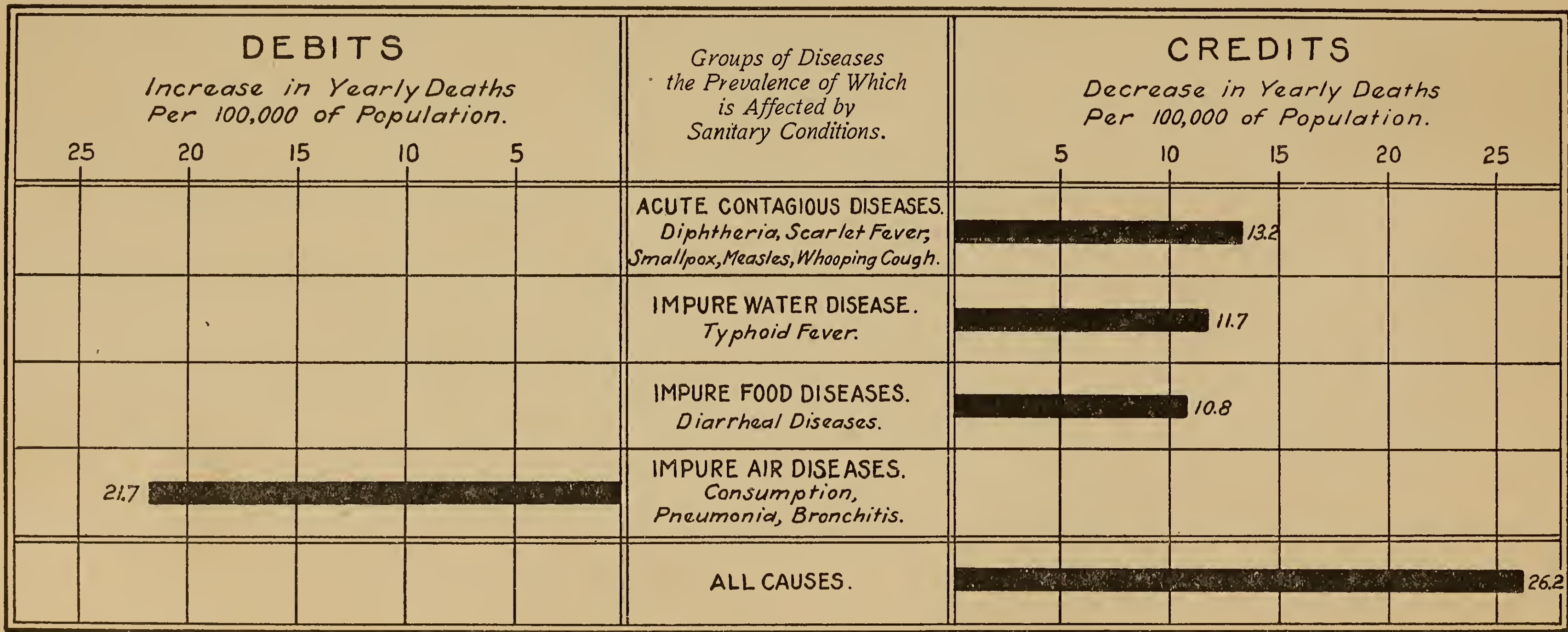
It is true that the railroads contribute to the growth of cities and above all to that of our city, and we should therefore be tolerant of them.

It is also true that they get a large part of their support from the acreage concentration of the people. That very concentration, in the last analysis, is responsible for a large part of their business. Whatever is done by railroads or others to make cities impossible or undesirable will work to the ultimate harm of the railroads. Were the air so laden with smoke that people would scatter out to ten to the acre, the railroads in common with all other industry would suffer greatly.

Therefore it can be assumed that the railroads of broader view will act as extra-governmental aids in the preservation of the air supply.

SANITARY BALANCE SHEET

An accounting of the mortality from certain groups of diseases the prevalence of which is affected by sanitary conditions. A comparison of the average death rates of the last five years, 1903–'07, with the average of the preceding five, 1898–'02 showing increased mortality from the impure-air diseases, decreased mortality from impure-water diseases, impure-food diseases, acute contagious diseases, and from all causes. Impure-air-disease deaths have increased at the average yearly rate of 21.7 for every 100,000 of the population, while from the acute contagious diseases they have decreased 13.2, from the impure-water diseases they have been 11.7 fewer, from the impure-food diseases 10.8 fewer, and from all causes 26.2 fewer.



THE PREVENTION OF SMOKE IN CHICAGO

PAUL P. BIRD

Chicago has grown up during the last half-century to meet the demands of trade and commerce. As a city it has been hurriedly put together after no very well thought-out plan or scheme. To-day, from a number of different angles, the citizens are endeavoring to make Chicago a better city to live in, a cleaner, and, physically, a more attractive one.

It is admitted by every one that the smoke nuisance in Chicago is one of its most serious handicaps. In fact, the abatement of this smoke nuisance is a necessary pre-requisite to the permanent success of these many organized movements for civic betterment.

The prevalence of such quantities of smoke in the atmosphere of Chicago is due to the almost universal use of soft coal from the adjacent Illinois and Indiana coal fields. Among the other splendid advantages due to Chicago's location that has helped to make her the commercial center of the Middle West and the manufacturing center of the world, is the fact that these immense coal fields lie at her very door. Here is found an excellent grade of bituminous coal, one of the best steam-making coals known, but which, unfortunately, when not burned under proper conditions, is a great smoke producer.

There is no question but that the power and heat used in Chicago must always come from this local soft coal. It would be an economic blunder to try to do anything else. The anthracite coal fields of Pennsylvania are so far away that the freight rates make hard coal prohibitive for general uses, and, moreover, authorities claim that the supply of anthracite, at its present rate of consumption, will be completely exhausted within sixty or eighty years. Therefore, the problem that the citizens of Chicago have before them is, not to abate the smoke nuisance by burning anthracite or even semi-bituminous coal, but to burn these local coals in such a manner that there will be complete and smokeless combustion.

For years there has been a smoke ordinance in Chicago. It has been left to the present city administration, however, to realize the importance to Chicago of smoke suppression and take up the question with vigor and intelligence.

With the advice and aid of a commission of eight business men, the Mayor has organized the bureau into one of the principal departments of the city's government. Its head and his assistants are mechanical engineers, and the crusade has been begun in a business-like and scientific manner.

The smoke of Chicago divides itself into three general classes: The smoke from stationary power-plants, whether in buildings, factories, or power-houses; smoke from locomotives; and smoke from tugs and vessels. Each constitutes a problem by itself.

The abatement of smoke from stationary plants, even when burning the cheapest of local coals is both possible and practicable. It is admitted by all scientists to be theoretically possible, if burned in a proper installation of boilers and furnaces operated with the requisite care. That such conditions are practical under commercial conditions is proven by the hundreds of plants in Chicago that are already operating without making objectionable smoke. It is an encouraging fact that a smokeless plant is always an economical one, and that, from the standpoint of the coal bill, it pays to have a clean and smokeless chimney.

There are over 11,000 stationary power-plants in Chicago. The majority of them have been installed without any adequate provision for smoke prevention, and, until recently, operated without attention or care. Under the present law, the plans for all new plants must be submitted to the Smoke Department before work is begun, and the Department compels the builder to make the very best provision for the prevention of smoke. As the old plants wear out and would be replaced by new and proper ones, the smoke from stationary plants would thus be gradually eliminated. The ordinance, however, contemplates a more immediate remedy, and provides punishment by fines for plant-owners who will not take immediate steps to stop the emission of smoke from their chimneys. In practice, the Department offers to co-operate with such offenders in discovering what are the causes of smoke in that particular plant. If the plant-owner acts in a spirit of co-operation and promises to take immediate steps to remedy the defect, he is allowed a reasonable time to do so. If, however, he opposes the suggestions and fails to promptly co-operate with the Department he is sued in court, and continually sued until, under the stress of accumulating fines, he takes the necessary measures to clean up his stack.

During the first year of the operation of the reorganized department, which has just ended, more than five hundred violating plants have been taken up by the Department and brought to a satisfactory condition of cleanliness. These results have probably not been noticed by the ordinary citizen who is not particularly interested, but the results are being accomplished, and at the end of this first year it is certain that a considerable improvement has already been accomplished. Each year the improvement will be more rapid and more noticeable, and the final abatement of smoke from stationary plants is simply a matter of time, the efficiency of the Department, and the resources at its command.

The smoke from tugs and vessels is now under special consideration by the Department. The complaint of President Harahan of the Illinois Central Railroad that great quantities of smoke come from the river and harbor is well founded. While the number of tugs and other vessels is comparatively few when compared with the stationary plants or locomotives, and burn a very small proportion of the total amount of coal consumed in Chicago, they make proportionately a far greater amount of smoke, and this smoke is a great nuisance, both on account of its density and the fact that it comes out of the stacks so near the level of the bridges and adjacent buildings.

The tug problem is different on account of the necessary high power of the engines, the limited space for boilers and furnaces, the laxity of former administrations toward the tug and vessel owners. and the fact that this branch of smoke prevention has not received the amount of scientific study as has the stationary plant.

The shipping season of 1908 was opened before the Department was organized to give the matter proper attention, and it was obvious that any changes of equipment would have to be made during the winter lay-up. A special deputy inspector has been assigned to study the problem during the entire summer, and during the winter plans will be developed to carry on an aggressive campaign with the opening of navigation next spring.

In the railroads the department has an entirely distinct problem. The many limitations in size and weight, and the unusual requirements of a locomotive prohibit the use of many arrangements and devices which bring about smokeless combustion in stationary plants. In a modern high-powered locomotive an enormous amount of coal is consumed and an enormous amount of steam generated per hour and amid very difficult conditions.

The first of these conditions is the construction of the fire-box of a locomotive. This, in itself, makes it difficult to operate without making smoke. The gases from the burning coal upon leaving the grate come in contact almost immediately with the metal of which the fire-box is composed. This metal is at a temperature of several hundred degrees lower than that of the burning gases, and they are cooled before an opportunity is given them to be entirely consumed. The combustion is only partial and the result of incomplete combustion is always smoke.

The fireman handling his fire must exercise greater care and skill than is needed with a fire in a fire-brick enclosed furnace where the gases are not subject to the cooling effect that they are in a locomotive. In fact, he must overcome to a certain degree by this care and skill, the effect of the cooling surfaces which are readily taken care of in a furnace or fire-box that can be properly designed.

The variable-load factor is another condition which confronts the fireman on a locomotive. At one instant a locomotive boiler may be generating steam to its fullest capacity and the fire in a condition to furnish heat to generate this steam, and at the next instant the demand for steam upon the boiler be reduced to practically nothing. It is impossible to control the fire to meet this condition and the result is generally considerable smoke.

Locomotives in service are sometimes required to run for 10 or 15 hours before an opportunity to clean fires is obtained. Probably a large per cent of this time the fireman is trying to operate his fire to meet the demands of steam in the boiler. This task is a very difficult one since a locomotive grate is none too large when the fire is in good condition to furnish heat enough to operate the boiler to its fullest capacity.

There are other minor conditions which make it difficult to operate a locomotive without smoke, such as accidents, break-downs, leaks in the fire-box due many times to poor water, and the like. All of these tend to increase the difficulties of operating steam locomotives without smoke.

Moreover the draft is obtained by exhausting the steam from the engines through the stack which is only a few inches in height, and the smoke, no matter how light it is, is discharged so near the ground level that it forms a decided nuisance to everyone.

The experience with the railroads during the year has been briefly as follows: At the start the whole matter was discussed with the presidents of the various roads entering Chicago, by the Smoke Abatement Commission, and the roads promised their co-operation and help toward reducing to a minimum the smoke caused by their locomotives.

Special deputy smoke inspectors, mechanical engineers with railroad experience, have been assigned to the railroad problem. The railroads have given the city department splendid co-operation, and a wonderful improvement has been made. This improvement is not so noticeable to the ordinary citizen who is not watching it particularly, but to the railroad operatives and to the city smoke inspectors the change has been marked.

Of all the railroads entering Chicago there are now three that are doing particularly well, and on these roads it is believed that the performance of steam locomotives is nearly as free from the smoke nuisance as is practicable. In the future there may be times when they will do better, and also there may be times when they will not do as well, but, on the whole, we have reached about as high a degree of cleanliness as is practical with steam locomotives using soft coal. However, on these roads, we still have the smoke nuisance, and it is a real nuisance. These locomotives are operating within the requirements of the present smoke ordinance as regards the emission of dense smoke, but still the rain of cinders and the sprinkling of dirt continues.

As stated above, the large users of steam in Chicago must use Illinois soft coal, and we may always expect steam locomotives in this district to use this fuel, and, as the other smoke conditions in Chicago continue to improve, this smoke from locomotives, even under the most careful operation, will become a much more evident nuisance.

Concerning the railroad smoke, the Department has reached this conclusion: *The eventual and final solution of the smoke and dirt nuisance on the railroads lies in the use of some form of motive power other than the steam locomotive.* Electrification offers the best and most promising solution of the problem. With a railroad terminal operating electrically, the power still comes from Illinois coal, as this fuel would be used in the power-houses where the electricity would be generated, but the coal could then be burned without smoke.

The present policy of the city Department of Smoke Inspection, as far as railroad smoke is concerned, is to keep the roads to the highest possible standard of cleanliness while using their steam locomotives and to aid and encourage, in all possible ways, the adoption of electricity.

THE RAILROADS AS SMOKE PRODUCERS

G. E. RYDER

To say that the railroads of Chicago do not smoke would be a well-recognized untruth. It would be as great a misrepresentation to say that the greater part of the smoke in Chicago comes from the railroads. The railroads in Chicago are not responsible for as much smoke in proportion to the amount of fuel they burn as are other consumers of coal. The steam craft on the river and in the Chicago Harbor, on the other hand, are responsible for a percentage of smoke many times the percentage of coal they burn referred to all the coal burned in Chicago. It is a conservative estimate to say that the railroads burn inside the city limits of Chicago 15% of all the coal that is burned in Chicago. And it is also a conservative estimate to say that the smoke from the railroads in Chicago constitutes less than 10% of the total smoke in the Chicago atmosphere.

When considered from the standpoint of a public nuisance the smoke, together with the noise, dirt, and cinders made by steam locomotives both in round-houses and on the road, stand at the head of the list. This nuisance is more objectionable than the smoke from all the rest of the coal burned in Chicago.

Manufacturing plants which use coal for fuel are generally located in a district where smoke is not so objectionable as it is in residence districts. The immediate surroundings are factories. They are not of a character to be greatly damaged by smoke and dirt. Fires built in the furnaces of these plants continue to burn for several days, thus doing away with the smoke caused by building new fires. The conditions of a large stationary plant can be controlled. When the remedy is applied for imperfect conditions the cure is permanent. The personal element is a small factor in these plants.

The railroads on the other hand, traverse resident districts where the smoke made, though it be less than made in other localities, is more of a nuisance. The damage to property is greater because the property to be damaged is more valuable and more susceptible to damage by smoke and cinders.

The personal element in the operation of steam locomotives constitutes the principal means of preventing smoke. This means cannot be relied upon to any extent for permanent results. The principal reason for this is that the men who make up the element are continually being changed.

The round-houses are among the worst offenders. Many of these are located near the residence districts of Chicago. In the average-sized round-house seventy-five to a hundred locomotives are handled daily. The handling of these locomotives includes cleaning or building new fires in each one. This operation is recognized as a necessarily smoky one, even by the city smoke ordinance, inasmuch as it provides a period of six minutes during which time smoke is permitted to be emitted while the fire is being cleaned or a new fire built.

The adoption of electricity for a means of moving trains within the city will necessarily do away with this objectionable feature of smoke produced by the railroads.

THE POSSIBILITY OF SMOKELESS STEAM LOCOMOTIVE TRACTION

G. E. RYDER

It is entirely possible to operate steam locomotives without smoke and at the same time use bituminous coal for fuel. The conditions which make it possible to accomplish this must be favorable almost to perfection. The design of the locomotive, its boiler and fire-box, must be such that the laws of combustion will not be violated when coal is burned on the grates. If the engine is over-cylindered it will require an over-crowding of the capacity of the boiler and therefore over-loading the grate. This means an uneconomical use of coal both from a financial standpoint and from the standpoint of fuel economy. The result of incomplete combustion is always smoke.

The same is true of an engine that is loaded to or nearly to its capacity. The coal is only partly consumed because it is necessary to burn it at so high a rate and the result is smoke. It is very difficult to overcome this feature since it is economical practice for railroads to haul as large loads as possible with each unit of power.

Every locomotive that is put into service not only increases the operating cost, an amount equal to the value of the locomotive, but the cost of an engine crew and train crew. It is the practice of railroad companies, therefore, to do the greatest amount of work with the fewest number of locomotives.

In order to operate smokelessly the fire-box must be of a design to accommodate the proper burning of coal and must be equipped with a brick arch. The fire-box must be of sufficient depth to allow the gases time to be completely consumed before passing into the tubes of the boiler.

The locomotive must be equipped with a blower of considerable strength to furnish draft enough to burn the coal when the engine is not working steam. The boiler and fire-box must be kept in perfect repair to accomplish smokeless results. No leaky flues, stay bolts, or steam pipes can be allowed.

With this equipment it is necessary that good coal be used. This the railroads will not do for economical, diplomatic, and political reasons. When all has been done and said with respect to equipment, maintenance and coal, there remains the most important element in securing smokeless operation of the steam locomotive. This is the personal element — the engineer and firemen who are actually doing the work. They are human, and inasmuch as they are human, they become careless in their work and every example of this carelessness causes smoke. The firemen are continually being changed either by promotion or by discharge for failure to fill their positions.

On account of these continued changes the railroad companies are necessarily put to considerable expense to educate the new men and watch the old ones who show a tendency toward carelessness, if they desire to operate without unreasonable amounts of smoke. A majority of railroads in Chicago have men whose duty it is to look after the smoke, educating the green firemen and disciplining the careless ones. Some of these men have no other duties, while others look after this work along with other work. One railroad in Chicago has five of these men whose titles are "smoke inspectors," thus increasing its expense $800.00 or $900.00 a month for the prevention of smoke. Other roads have a less number and some have only one, as the demand requires.

While it is entirely *possible* to operate one locomotive or a thousand without making smoke, it is not economical to do so. There are expenses chargeable to equipment, maintenance, and superintendence which exist only on account of endeavor to prevent smoke. These expenses, as well as many others mentioned in this report, would not occur if trains were operated by some other means than direct steam operation.

There have been many so-called smoke devices for locomotives put on the market, proving either partial or total failures in almost as many cases. Description and history of these devices would be beyond the scope of this report. They are along the lines of specially designed arches, blowers, and means of admitting air over the fire. In each case these devices have tended to better conditions but have not given entire satisfaction to any universal extent. These devices had their birth and have met with some success in the engines which they were first designed for. The reason of their success in these instances was probably due to the fact that they were the proper remedy for conditions already good. When they have been tried to any universal extent they have proved inefficient.

There are two methods left for smokeless steam locomotive operation which are absolutely certain, i e., the adoption of anthracite coal or coke. Either of these fuels is absolutely smokeless in as far as

Courtesy General Electric Co.

New York Central & Hudson River Railroad — Typical Section of Electric Zone – Harlem Division — Direct-Current Third-Rail Construction.

visible smoke is concerned. There are, however, gases which arise from these fuels which are probably as destructive to vegetation and as detrimental to the public health as the visible smoke and invisible gases which are evolved from bituminous coals.

The use of these fuels eliminates the personal element in the operation of locomotives, as far as smoke prevention goes, to a minimum. The cost of these fuels is almost prohibitive to their use. The bituminous coals used by railroads in Chicago range between $1.00 and $2.00 per ton. Anthracite would cost at the present market about $5.50 per ton. Considering bituminous coal at $2.00 per ton, the adoption of anthracite coal would mean an increase in cost of 125%. The increased efficiency of anthracite coal is only about 10% over bituminous, which would make an increase of 115% in the cost of fuel. If coke were used the increase in cost would be approximately 75%.

If anthracite coal were adopted by the railroads for fuel in Chicago, it would reduce the market for coal from Illinois coal fields several hundred thousand tons per year, and it is not policy, even if the price were not prohibitive, to solve the smoke problem in Chicago by the substitution of a foreign fuel. It must be done and still use Illinois coal.

Further, if it were policy and it were possible to eliminate the visible smoke by the use of anthracite coal or coke, there would still remain the invisible gases, together with the noise and cinders of the steam locomotive. The noise is only unpleasant to our ears but the cinders are both destructive to clothing, houses, and vegetation in general, as well as injurious to the people who come in contact with them.

The solution, therefore, for these difficulties, is some means of power for the moving of trains in Chicago which will not necessitate the burning of fuel as it is burned at present on each unit, but that it be burned at some one place where all the conditions can be controlled and the power generated delivered to the unit in a form to be converted into work immediately.

The most feasible means of accomplishing this at the present time seems to be electrification. The adoption of this means of locomotion has met with success wherever tried, either in street railway, interurban, or trunk line service, both in this country and in foreign countries. Lines are now being operated successfully in New York City and there is no reason why the railroads of Chicago should not adopt this system. Of these railroads the Illinois Central is at the present time in the most favorable circumstances for its adoption.

ANTHRACITE COAL AND COKE AS REMEDIES

PAUL P. BIRD

Without considering any of the mechanical difficulties that might be encountered in using either anthracite or coke as fuel in the present steam locomotives, it would be a very expensive thing to do.

Considering only the cost of these fuels in Chicago and their heat values, it is estimated that the fuel bill of a railroad terminal using anthracite coal would be two and a half times larger than, and using coke twice as large, as with Illinois coal.

It is thus seen that the cost of these fuels would discourage their use. Also, we want to, if possible, use our local coals and not make another state richer by buying its product when we have one at home that can be made use of.

The only coke available for use by the Chicago railroads is made from Eastern coals. The local coals have still resisted all attempts to successfully coke them.

Further, it is doubtful that coke would prove a satisfactory fuel for a modern high-powered locomotive, due to its light weight, as the strong draft might carry the smaller pieces out of the stack before they had time to burn.

A number of the eastern railroads in the anthracite region use hard coal successfully, so we are sure that no difficulty would arise from its use here, other than the cost.

The cost of hard coal is increasing rapidly from year to year, due to the exhaustion of the supply. Scientists estimate that the supply will be completely gone within sixty or seventy years.

The use of either of these fuels would undoubtedly do away with the railroad smoke, but the cinders would remain as well as the other nuisances due to the use of steam, such as the noisy escape of steam from the safety valves while the engines are standing still.

In general, it would not be advisable to use coke or anthracite coal when electrification offers such pronounced advantages from all viewpoints.

THE GENERAL ASPECTS OF ELECTRIFICATION

H. H. EVANS

Public attention in large cities, and particularly in Chicago, is largely held by two subjects — increased cleanliness of the city at large and better transit facilities. The first of these is essential to the welfare of its citizens, the second is vital to a city's growth. There is little need of harping upon the advantages to accrue from better transportation facilities. A realization of what they are comes to each citizen of Chicago by virtue of his living in a community which has had the most marvelous growth ever known, largely because of the unequaled railroad connections which the energy of its citizens has been able to attract. But the energy of its citizens has not stopped with securing better railroad facilities with other cities; they are seeking, as well, better facilities between the city and its suburbs and within the city itself. It will facilitate business, make more comfortable the life of a good many citizens, and knit the city into a unity. Altogether, it is an end greatly to be desired. And the other is equally important. Cleanliness in Chicago is attractive ethically, but vastly more so economically. Dirt costs money — a great deal of it. Almost every citizen pays toll to the smoke nuisance in increased living expenses in some form or other. Merchants and manufacturers pay it in tangible form. No one denies that to get rid of it would be desirable. While the railroads consume but 13% of the coal burned in Chicago, it is generally observed that they contribute most to the public's suffering. This is because locomotive construction and working does not admit of smoke consumption, because the railroad locations in Chicago are such as to distribute the smoke where it is particularly obnoxious, and because the traveling public has to place itself on its journeys directly in the path of trailing smoke.

The interest of the public being so large in these matters, the public has cast about to see what will further its aim. Electrification of the railroads has presented itself as the most efficient means. This has not been a sudden conviction upon its part, but has been forced upon the public by experience. A number of years ago almost every city had somewhere about it a steam dummy line heralded as an expeditious and attractive means of transit. Some cities had them along most of their principal streets. Electric trolley roads made their appearance with their full share of discouragements. Added to the difficulties which must invariably be overcome with new apparatus, their projectors were met with predictions that the system would not work, that it would not be reliable, that it could never pay interest charges upon the huge investment involved, and the current catchword was the "deadly trolley." Tried out, the public found electric street railways safe, cleanly, comfortable, expeditious, and economical. The steam dummy line has become a curiosity.

A few years ago we had steam trains upon the elevated railways. The convenience of these roads was such that the public soon taxed their resources. It became necessary to adopt some change in system which would admit of a greater traffic movement over their tracks. This showed itself earlier in New York than in Chicago, and as early as 1885 the Manhattan Elevated made electrification experiments upon a portion of its tracks. It was, however, reserved to Chicago, with its practical demonstration of the Intramural Road at the World's Fair and the subsequent electrification of the elevated railroads, to demonstrate the adequacy of electrification. Now, in its essentials, the problem presented by the electrification of the elevated railroads is pretty much that of the best-developed suburban services of the standard railroads. Take the cases of the Illinois Central local suburban service to Sixty-third Street, and that of the Alley Elevated at the time of its electrification (work begun 1897, service put on April 23, 1898). For the local suburban service the Illinois Central kept two tracks distinct from its other service. Both were double-track roads with one track reserved for north-bound and one for south-bound traffic. Neither had any crossings over its right of way. Stations in each case were one-half mile apart; the passengers in both cases were unloaded and loaded onto and from platforms at the same height as the car floor. The locomotives used were of the same characteristics — that is, the elevated locomotive and the Illinois Central suburban locomotive were more nearly alike than the suburban locomotive is like the standard passenger locomotive. Approximately the same character and weight of trains were handled. The elevated, of course, ran more trains than the Illinois Central, because of its policy of handling a larger number of passengers at a smaller fare. The Illinois Central made somewhat better speed at a cost of reduced capacity. The district contiguous to the elevated was more sparsely populated in 1897 than now, so it is probable that at the time the population served by the two roads was sensibly even. They handled the same class of traffic — a large crowd going to or from work during the rush hours and a shopping crowd in the middle of the day. Both streaked smoke through the residence district and converged upon the business district. The public has seen electrification work so vast an improvement in the elevated roads that it cannot but ask why such an improvement would not be possible with the standard steam railroads. The facilities which are now afforded by the South Side Elevated (formerly the Alley El) could not be duplicated under steam working. Inability to make the speed, inability to haul the heavier trains now hauled, inability to be at the entrance to the loop on the second, and inability to dodge on and off the loop within the few seconds afforded, would all militate against it. During the rush hours these cars come onto the loop under a 22-second headway and for a brief period in the morning rush hour, on a 12-second headway. The Metropolitan does the same. The South Side Elevated has increased its speed of locals from that of 12 miles per hour to 15 miles per hour, including stops. It also hauls 6-car trains instead of 4-car ones. Mr. Brinckerhoff stated before the American Street and Interurban Railway Association in 1906, that in ten years the passengers carried rose from 13,587,791 to 32,959,752. Very curiously, despite the higher speed (which would argue an increase) the cost of working per car mile by electricity was $0.089 against $0.105 by steam — a decrease of 16%. And in every case in the United States where an elevated railroad has been electrified, there has followed an increase in car movement afforded the public, an increase in the passengers carried (showing its appreciation by the public) and a decrease in the cost of operation per car mile.

Interest has been further drawn to electrification, by the remarkable growth of the interurban road. So long as these roads were only modified street railways making use of public highways and stopping at random, or so long as they went into territory not reached by the railroads, they attracted little attention. But soon they began to get into the territory of the steam roads and presently there evolved an electric railroad connecting the same termini as a portion of a steam railroad, running upon its private right of way, with right-of-way construction equal to the most approved steam-railroad construction, equipped with block signals, and stopping at regular stations. Here, then, was a new thing. Running heavy cars on a fast schedule, they afforded the public a frequent, convenient, rapid, and comfortable means of transit. By so doing, they have been able partly to attract to themselves, partly develop, a density of traffic which has been sufficient (where their projection has been wisely considered) to afford adequate returns upon the capital invested. This has come, too, from the development of local traffic which is popularly supposed not to be remunerative. In some cases, such roads have been built into virgin territory where, ten years ago, a steam railroad would have been the only one considered. Such roads may extend over hundreds of miles, have adequate freight and passenger terminals, and do a through passenger and carload-freight business. Take, for instance, the Spokane and Inland Empire System. This electric road is now operating 194 miles of railroads with over 300 miles of trackage. It has a terminal yard in Spokane 300 feet by 2,000 feet and a terminal freight-house 40 feet by 300 feet. In addition to its interurban passenger equipment it owns 16 electric locomotives, 5 steam locomotives and 530 standard freight cars. It does a local street-car business, a suburban and interurban business, a through passenger business, hauls mail and express, and electrically hauls freight in trains of twenty to thirty cars. Certain features of such roads and of the interurban roads have drawn the attention of the public to the possibilities of the electrification of the steam roads into Chicago. The argument from the public point of view ran somewhat along this line. The local transportation facilities of the steam roads are nowhere near taxed to their capacity; the public will not fill up the trains already at their convenience. Therefore it follows, first, that steam operation is adequate and, second, that the public does not care to travel. The interurbans have shown that there is a screw loose in this reasoning and that growth in travel comes fastest from travel becoming a convenience and a pleasure, rather than a necessity. There is really little excuse for the building of these interurban railways. Their field should have been occupied by the steam roads. These roads in many cases owned sections of track which could have been utilized for interurban service by adding the electrical equipment. Lately, this has been done on certain sections of the New York, New Haven & Hartford and of the West Shore, for instance. In other cases such as portions of the Northern Pacific and the Erie, certain unimportant lines have been turned into interurban trolley lines. At the very worst, additional tracks for interurban service could have been built alongside of the existing tracks at a less cost than an entirely new right of way could be built by an interurban line. That the interurban has been able to make better entry into a city would not be insurmountable, since certain steam roads, which have electrified interurban sections, have arranged to have interurban cars leave the right of way and pass into the center of the town over local street-railway tracks. This has been done, among others, by the Delaware & Hudson and the New York, New Haven & Hartford railways. When $5,000 a mile would have equipped a road for such service, it seems a pity that $30,000 to $35,000 a mile was expended in building an entirely new road, and that the difference could not have been available for investments which would prove of further advantage to society. There is a concrete case of this right to our doors. It is generally understood that certain railroads reaching to the westward, made investigations several years ago as to the feasibility of electrifying their suburban lines and decided adversely on the grounds of expense. That such was the case, the writer is not able to say definitely, but it seems very likely since these roads experimented at that time with motor vehicles and other devices for taking care of this traffic and it is to be expected that they would have investigated electrification. The Aurora, Elgin & Chicago went into this same territory, the traffic from which "would not pay returns upon the electrification" of roads already established, built a high-grade road from the ground up and pays 5% upon the investment. Whenever such a road has been built the preference of the public for the superior service afforded has been manifest. The steam railroads have suffered keenly from the competition and have vainly endeavored by reduced fares and other devices, to hold their traffic. According to an affidavit filed with the Indiana State Tax Board, in 1906, the passenger traffic of the Clover Leaf railroad dropped off 95% between points of interurban competition. Ray Morris, in the Atlantic Monthly (June, 1904) gave the following figures to show the falling off in passenger traffic between such points, despite a cut in fares by the steam roads:

L. S. & M. S.— Between Cleveland and Oberlin — 34 Miles

Year	West	East	Total	Per Month
1895	104,426	98,588	203,014	16,918
1902	46,328	45,433	91,761	7,647

L. S. & M. S.— Between Cleveland and Painesville — 29 Miles

Year	West	East	Total	Per Month
1895	97,460	101,832	199,292	16,608
1902	13,106	15,602	28,708	2,392

N. Y. C. & St. L.— Between Cleveland and Lorain

Year	Total Passengers	Revenue	Average Revenue
1895	42,526	$25,523	$0.60
1902	9,795	4,379	0.44

A further commentary upon the preference of the public for electric traction is found in the history of our transportation facilities in Chicago. In the last five years the growth of the suburban steam-railway traffic has been small and the roads patronized only through necessity, while the elevated roads cannot keep their facilities abreast of the demands of traffic. Lastly, the preference of the public for electric traction may be shown by the experience of steam roads which have been electrified. On the earlier electrifications on the New York, New Haven & Hartford (in a paper published in the Street Railway Journal, Sept. 8, 1900) Heft gives the following figures for passengers carried:

	Steam	Electric
Nantasket Beach..................	304,292	702,419
Highland Div.....................	387,695	1,060,617
Berlin Branch....................	267,936	241,207
New Canaan Branch..............	98,302	184,728

On the electrified West Jersey and Seashore railroad, belonging to the Pennsylvania railroad, and running between Camden and Atlantic City, the strictly local traffic for the year ending August 31, 1907 (the first year of its electrification) showed an increase of 19.54% over the preceding year of steam operation, while the increase, in turn, of the last year of steam operation over the preceding one, was only 1.85%.

On the Mersey railroad out of Liverpool for a 6-months period, the passengers under electrification were 4,500,000 against 3,200,000 under 6 months of steam operation.

On the North Eastern out of Newcastle for 6-months periods, the passengers were 3,548,000 under electric working against 2,844,000 under steam.

On the Lancashire and Yorkshire, out of Liverpool, the traffic under electrification increased by considerably over 100,000 passengers per month.

On the Milan-Gallarate-Porto Ceresio line in Italy, early reports showed yearly passenger receipts of 993,150 lire under electric working against 663,000 lire for steam, and this, despite a reduction in fares subsequent to electrification.

With these lessons of the past in mind, and the smoke being intolerable, electrification of the steam railroads in Chicago has become a question of interest to every citizen. An index of the interest is afforded by the persistent clamor of the daily press. This clamor is more to be heeded since the press has been kept in ignorance that this investigation was being conducted. Not only the press, but the representative business organizations have taken a hand in asking if electrification could not be applied to railroad terminals in Chicago. Thus the Hamilton Club, last April, addressed letters to various officials of the railways entering Chicago, asking an expression of opinion regarding the electrification of these roads. Varying replies were received.

J. T. Harahan, president of the Illinois Central Railroad Company, wrote Mr. Morris as follows:

"With regard to the substitution of electric power for steam on locomotives, I would say that it is a large question and one which cannot be answered offhand. The electrification of steam railroads as far as pertains to the handling of business outside of cities is a simple question, but when it comes to the electrification of large terminals like those of the railways of Chicago it is an entirely different question.

"The experience in the electrification of the New York Central terminals in New York City has developed many difficulties, one of the greatest of which is a financial one. It is apparent to any business man that he cannot afford to make a large initial outlay unless such outlay is compensated by a reduction in the cost of operation. The exact contrary has been the experience with reference to the New York Central terminals in New York City.

"The art of electrification of steam railroads is yet in its infancy, and the experience has not been sufficient to demonstrate the most economical type. There is no question, however, that with the advancement of the art the future will see a large development in the electrification of existing steam roads. It is not possible, however, in any business, to set aside the present plant in which there is a large investment, and make a further large initial expenditure to provide an entirely new equipment. I think it must be recognized as an economic fact that large outlays of money cannot be made without compensating returns.

"With reference to the abatement of the smoke nuisance, it has been our purpose in the past, and will be in the future, to coöperate with every movement that tends toward the suppression of this element, and we are constantly on the alert, training our men and disciplining them in the correct method of using coal on our locomotives. The fault, however, does not entirely lie with the railroads. If you will observe the volumes of smoke made by factories and vessels entering Chicago Harbor, I think you will reach the conclusion that even with the elimination of the smoke nuisance by steam locomotives, only a small part of the nuisance will have been abated."

The Chicago, Milwaukee & St. Paul Railway Company, through its second vice-president, E. W. McKenna, stated its opinion to Mr. Morris in these words:

"The substitution of electric power for the operation of the enormous maze of switches and tracks of the terminal yards of the Chicago railways, in the present development of the art, would be impossible and impracticable.

"The railway companies are doing everything possible for the abatement of the smoke nuisance, and have equipped their engines with the best-known devices, and are expending considerable sums of money in the oversight of the performance of their men in this respect.

"There does not seem to be any good argument that the railroads have been lacking in spirit in respect to the maintenance of freight and passenger terminals. Railway companies, the same as other large enterprises, can only travel in the direction they desire to go to the extent of their resources. The expansion of traffic in Chicago has been rapid, and railway companies are constantly outgrowing their facilities. The increased cost of land and other items entering into the expansion of such facilities in the large cities frequently prevent them from going forward as rapidly as they would desire, but it is a reasonable argument that they have fairly met their responsibilities in this respect."

Now these are replies of men interested and entitled to respect. At the same time, they are offhand statements of individual men. That they are not final is shown in the attitude of other equally responsible officials. In March, 1907, the New York Times contained an interview with Mr. E. H. Harriman, in which, speaking of electrification in general and inspired by Mr. Hill's calling attention to the demand for larger railroad capacity, he is quoted as saying:

"But perhaps it is chimerical to think now of rebuilding the railroads of the entire country and of replacing the entire railroad equipment. If so, what is the best thing? Obviously, electricity. And I believe that the railroads will have to come to that, not only to get a larger unit of motor power and of distributing it over the train load, but on account of fuel. That brings up another phase of the existing conditions. We have to use up fuel to carry our fuel and there are certain limitations here just as much as there are in car capacity or motive power, particularly when you consider the distribution of the coal-producing regions with respect to the major avenues of traffic. The great saving resulting from the use of electricity is apparent, quite aside from increasing the tractive power and the train load. . . . The only relief which can be obtained through economies of physical operation must come through the outlay of enormous amounts of money, such as would be involved in a general electrification or a change in gauge."

From this statement we take it that Mr. Harriman believes in the feasibility of electrification. We further understand Mr. Harriman to mean that the electrification of an entire railroad system may be desirable when the traffic density rises above a certain point. We reason that such a point has been reached in Chicago, for it is impossible to conceive of a greater density of population with its induced density of traffic lying along the entire length of a railway system, than that which lies along those portions of the railways which are within the city limits of Chicago. As to the density of traffic in Chicago (with the accompanying devices for its care) rendering it a physical impossibility to install devices for electrical working, we believe Mr. Harriman too astute a manager to suggest a remedy for certain conditions, when those very conditions, by their complication, make impossible the application of the remedy.

It is a significant fact that the testimony of those who have been intimately connected with the electrification of roads under dense traffic conditions, and who are thus best in a position to judge, has been favorable. Thus the trend of a paper read by Mr. W. J. Wilgus before the American Society of Civil Engineers, on March 18, 1908, on the "Electrification of the Suburban Zone of the New York Central & Hudson River Railroad in the Vicinity of New York City," was distinctly favorable. Mr. Wilgus was chief engineer and, later, a vice-president of the New York Central during the electrification. Mr. T. E. Byrnes, vice-president of the New York, New Haven & Hartford, in an interview printed in the Boston Herald of July 3, 1908, is quoted as saying:

"We feel that the experimental stage of the electric railroad has practically passed and that our system has been demonstrated to be successful."

He is further quoted as announcing the ultimate electrification of the entire New Haven system. Vice-President E. H. McHenry, of the New Haven, in an article published in the Street Railway Journal, August 17, 1907, says:

"A general change from steam to electricity will render unproductive a very large amount of invested capital and create the necessity for the expenditure of additional amounts still greater, but there is no reason to doubt that the transition already in progress will be rapidly extended and applied to all points where congested terminals, high frequency of train service, and low costs of power create favorable conditions."

President Charles S. Mellen of the New Haven has been quoted by the press as being very favorable to electric traction. A report of the Committee of the American Railway Master Mechanics' Association in 1906, was favorable to electric handling of dense suburban traffic. Shortly after the electrification of the Mersey road, Mr. James Falconer, chairman of the Board of Directors, gave some operating figures and said: "These figures conclusively established the superiority of electrical traction over steam traction in dealing with such a railway as this." The half-yearly report of the North Eastern railway of England, early in 1906 stated: "Further experience in electric traction of the suburban lines in the Newcastle district, has been entirely favorable from a practical and from a financial point of view." Speaking of the Lancashire & Yorkshire electrification, Sir George Armytage, at the semi-annual meeting of the company in February 1906, stated: "They had been able to do a greater amount of work and had given a better service to the public which would have been absolutely impossible under the old conditions."

Existent electrifications extend over a very wide scope. There are almost a score of them in the United States. Almost every country in Europe contains one or more. They vary all the way from a two-mile section of track electrified to supply a link in an allied street-railway line to full terminal electrifications in large cities. There are some which were installed merely to get freight through a tunnel or over a mountain division; there are others which comprehend the entire working of a trunk line. Some handle an enormous passenger business—others handle purely freight. None presents precisely the same situation as that encountered in Chicago. There is no phase of the Chicago situation, however, which cannot be found present in some degree in one or more existent electrifications. These, it is our purpose to take up in detail in a later chapter. One feature is notable. The more important ones are being extended. This is true of the New Haven and the Long Island electrifications in this country. Both the terminal roads into Paris are extending their electrified zones. The Lancashire & Yorkshire and the North Eastern in England, have made extensions. The very important Italian electrifications have been extended from time to time,— now an extension of 193 miles has been entered upon. The Prussian Minister of Public Works in the Prussian Diet, January 26, 1904, said: "The studies are still in their preliminary stages. We cannot undertake the transportation of the general passenger public electrically. It is still uncertain whether such roads can be economically profitable. The experiments will be continued with necessary precautions." Certainly he could not have been more conservative. We now find the Prussian Government entering upon the electrification of 226 miles of the Berlin Stadt und Ringbahn, and of the 112 miles of double track belonging to the Eifel Bahn.

All of this goes to show that the replies of the gentlemen to the Hamilton Club are not final, and that there is room for an honest difference of opinion to exist.

It shall be our purpose to lay before your honorable body, the information which has come to our hands and the reasons pro and con regarding electrification, which have been advanced, or which have occurred to us, for your assistance in dealing with this matter. It shall be our purpose to inquire into the advantages to the public claimed for electrification and those to the railroads; the disadvantages of electrification; its feasibility and practicability. It may be that, without regard to what is due the public, the opportunities for economy presented may be sufficient to cause the railroads to decide to electrify. This is believed to be the cause of the New Haven's extensive electrification and is the avowed cause of the bulk of the electrifications in Italy, Austria, Germany, Sweden, Belgium, and Switzerland. It may be that certain inherent advantages and opportunities in electric working may be so great as to outweigh to the railroads any tangible economy to be presented. This might be the case where more extensive working of terminal facilities becomes available or a greater attractiveness to passengers is expected to bring increased traffic. It is analogous to the situation at the stock yards, where the packers spend large sums in keeping their plant clean in order to continue the popularity of their product with the public. This is said to be the reason for the Erie electrification in New York State, and of the Long Island railway's electrification. It is the reason of the various British electrifications, with one exception. Again, it may be that public comfort or convenience will be found paramount to whatever effect it may have upon the railways. Thus, conditions of public safety and comfort required the exclusion of the gases in the tunnel leading to the Grand Central Station in New York City and the New York Central was required to electrify the traffic through the tunnel, by an act of the Legislature of May 7, 1903, this being brought about because of the accident of January 8, 1902, with its large casualty list. Lastly, it may be found that the advantages to the public would be small and the burden to the railroad large, so that to ask them to electrify would be onerous and unreasonable.

Considering, now, what electrification would mean to the public, the first thing which suggests itself is the ridding of the city of the major part of the smoke, smell, noise, dust, and cinders incident to steam-locomotive operation.

Let us examine whence this amelioration should come.

In either case coal is burned. Instead of burning coal in the locomotive boiler and generating power at the locomotive, the coal is burned under the boilers of a power-house where electrical power is generated and transmitted to the motor. Owing to its being burned under better conditions and to the more efficient application of motive power, a smaller quantity of coal is consumed per unit of power delivered at the axle under electrical working, than under steam traction. For terminal service this is in about the ratio of one or two. Under electrical traction we are, therefore, only using about half the coal with its smoke-making possibilities, to begin with.

Instead of a number of locomotives spouting smoke up and down the railroad, one power-house is substituted. This power-house can be located, if necessary, outside the city — certainly away from residence districts and business and factory districts where close confinement of workers is required or where materials are kept which will suffer damage from soot.

The smoke of locomotives is delivered low down between close walls of houses where there is no chance for the wind to disseminate it. The products of combustion from a power-house stack are delivered high up where they have a chance to be so far diluted as to become innocuous before settling.

Smoke prevention is dependent upon completeness of combustion. The construction and working of a locomotive boiler do not favor perfect combustion. Absolute freedom in the choice of a proper kind of boiler is allowable with a central power-house.

Chain grates, Dutch-oven furnaces, fire-brick arches in the combustion space, and other devices aid in the suppression of smoke. The use of some of these devices is hindered, of others precluded, in a steam locomotive. The limitation comes from two directions: first, space limitations in a locomotive are such as to prevent their installation where they are in constant view or are readily accessible — this being necessary for their efficient maintenance and working; second, the cost of these devices per horse-power decreases very rapidly with increase in size of the boiler or plant to which they are applied. In a locomotive boiler, the interest on the cost of their installation, and the upkeep, would overbalance the saving in fuel; while applied to a power-plant it would be the other way. Because of economies presented, their installation in a power-plant would come of volition, while their adoption for locomotives would be coercive.

The personal element enters largely into the production of smoke by a steam locomotive. Suppose that the construction and appliances of a locomotive were favorable to perfect combustion. Personal attention would still be necessary to ensure it. There are several hundred locomotives in Chicago which demand several hundred firemen to take care of them. (Somewhere around 600 locomotives.) There are bound to be inefficient and careless firemen among these hundreds, who produce smoke. In the power-house you have one man in charge of each shift who can see to it and be held responsible that there is no smoke. In addition to the ideal steam locomotives which we have supposed, we will further suppose that the single idea of finding men who can prevent smoke is pursued (which it cannot be). It is mathematically easier to find three perfect men to take charge of the shifts in a power-house boiler-room, than to find six hundred perfect men to put on the locomotives. Suppose, for the moment, that equally capable and conscientious men were secured for the two places at the outstart. Boiler-room duties are simple and the demands steady; a fireman's duties are manifold and the demands extremely variable. Therefore we would expect the boiler-room man to develop into a smoke-prevention expert; this would be asking too much of the locomotive fireman.

Because of clearance limitations, for structural reasons, and because of the necessity for a rapid passage of exhaust gases in order to get capacity, a locomotive stack cannot be otherwise than short and of small cross-sectional area,— both of these characteristics, in that they admit of neither time nor space requisite to bring into intimate mixture gases and solid matter which might otherwise combine while hot,— are productive of smoke. A power-house affords an opportunity of supplying the most efficient form of stack and the working of several boilers attached to one stack affords an opportunity for an excess of hot air from one boiler to consume in the uptake a surplus of carbonaceous matter rising from another before both are discharged into the atmosphere and cooled below the temperature of ignition.

The locomotive must employ a steam jet in the stack to get draught. This lifts up volumes of cinders, ashes, and sooty matter and discharges it into the atmosphere along the track. With the slower passage of gases in a power-plant boiler, this action is absent.

The moist steam in locomotive smoke makes the soot cling more tenaciously to individuals and buildings.

The demand on the furnace of a locomotive is intermittent — jerky. When the speed is suddenly increased, the suction of the air past the stack sucks up volumes of smoke and dust; this is aggravated by the fact that the fireman has usually put on fresh coal a short time before in anticipation of the increased demand and the surface of this coal has not yet been cemented by the heat. In the power-house, the demand is continuous and even.

The locomotive is continually dropping ashes along the road which are scooped up by the train in its rush and scattered to the atmosphere, — this fine dust being extremely irritating. With electrically-propelled trains making no dirt and with rock ballast, eventually the track should be free from dirt and there should be no more dust in travelling along it than is encountered in a street car.

Certain noises inherent to steam locomotives would be done away with by electrical working such as the noise of the reciprocating parts and the puffing smoke-stacks. Others would be minimized because of the even action of an electric motor as opposed to the reciprocating movement of engine parts.

This detailed examination leads us to believe that a larger percentage of the smoke nuisance in Chicago comes from the railroads, than a consideration of the railroad coal consumption being 13 per cent of the total coal consumption would at first indicate. Merely as an estimate, we should say the smoke producing tendency with railroads is intensified somewhere around three times the average. This would mean 35 to 40 per cent of the smoke nuisance in Chicago is due to the railroads. With their convergence upon the loop district and the large yards at their termini, we are led to believe that 60 per cent of the smoke in the loop district may be laid at the door of the railroads.

Besides the increased comfort of the public at large and the increased attractiveness to those who use the railroads, the removal of this smoke and dirt would work an economy to the community. Some of the savings which would ensue, are:

1. A large saving in merchandise now damaged by soot. In a mercantile business this now demands the imposition of from 1% to 10% burden, depending upon the perishability of the stock handled.

2. A saving in the extra amount expended for cleaning windows, hangings, and furnishings, for periodically cleaning stone and brickwork, for more frequent painting, and for increased personal expenditures. As to extra cleaning of stonework, take the case of Denver where there are a great many stone houses of delicate tints, but where the atmosphere

is clean,— the necessity for cleaning stonework, there, is extremely rare. As to painting, perhaps the best case of segregation of paintwork where nothing but atmosphere dirt (mainly smoke) can affect it, is in the case of vessels of the United States Navy. Steam vessels are usually painted two to three times a year — sailing vessels but once. As to increased personal expenses, a small example will suffice. It is a frequent matter of comment by people who come here from other places, that linen will stay fresh in Chicago only one-half as long as elsewhere. There are at least 200,000 men in Chicago who are affected by it. Three extra collars a week in the laundry for them means $12,000 a week toll to smoke, or $624,000 a year — enough to pay interest, sinking fund, and taxes upon the investment in purely electrical equipment for the electrification of two entire railroad terminals.

3. Property values would be largely enhanced through the furnishing of more attractive means of transportation in the outlying districts and through the greater comfort and less care required for housekeeping closer in.

4. A saving through the better health of the community due to purer air in working and living spaces. This has a tangible value to be reckoned in the value of workers' time saved from sickness and an intangible value arising from the greater efficiency and capacity for work of men who are in better physical condition.

5. With hot cinders eliminated, it is probable that there will be a slight saving in fire loss. It seems reasonable to suppose that a slightly reduced insurance rate could be secured for grain elevators and lumber yards with the locomotives taken out of proximity to them. The possible saving to an operating company in insurance premiums, through maintenance or construction of a plant in such a way as to reduce the fire risk, is very well brought out in the recent report of President Mitten of the Chicago City Railways, regarding the insurance carried by that corporation. A tabulation of this is quoted as follows:

	Insurable Property	Insurance Carried	Rate	Premium
July 1905	$5,300,000	$2,300,000	$2.22	$51,060
January 1906	6,441,869	6,441,000	1.00	64,418
January 1907 ...	7,442,500	7,442,500	.82	60,864
October 1907	9,660,000	9,660,000	.68	65,688
June 1908	9,775,000	9,775,000	.60	58,650

By adopting a fire-proof construction of barns and using other means to reduce the fire risk, this company is enabled to secure a rate of less than one-third of its old rate and is able to carry insurance on nearly $10,000,000 for less than was formerly paid for about $6,500,000.

6. With electrical working, it would be possible to extend the upper stories of industrial plants over the tracks now occupied by switch-tracks to these plants, thus rendering the ground available for double occupancy. This is being done in New York where the New York Central expects to cover its entire terminal yard with office buildings.

7. Not as a result of the abolition of smoke, but because of the greater facilities afforded under electrical operation, a great saving in time will result to those who have to use the railroads in transacting business.

While the abolition of nuisances makes a large appeal to the citizen, there is another large aspect. That is, the ability to afford better transportation facilities under electrification. The railroads occupy a large part of the city. Former routes of public travel have been given over to them and they possess broad avenues from where the people live into the heart of where they work. Their obligation to the public does not stop where their freight traffic has been cared for. They are capable of affording valuable passenger facilities to the public and it is to be expected that they will.

To come up the bank of the drainage canal is probably the only remaining avenue into Chicago, except at a forbidding expense. There is no more room for more railroads,— the present facilities must be developed to a higher intensity of working as time comes on. This, in itself, will force electrification at some future time. If, then, it is to come, why not have it now and let the people have the advantage of better local transportation facilities meanwhile?

There is just now a movement toward the suburbs. People want more room and better air. The city is daily becoming wealthier and a good many people would like to go farther away from the center of town if they could get back and forth from work without having to struggle with a time table. There are sparsely settled districts in the suburbs which need these people. The railroads run through them. Obviously, the thing to do is for the railroads to afford the local transportation facilities for them. Until a largely increased growth of population in them is induced, it will not pay to build electric systems to them. The quickest way to render them available to the people is to electrically equip the railroads to them. It is also the cheapest way, since the electrical equipment of the railroad will only cost a fifth of what an entirely new system would cost. It is also the quickest way to insure returns upon the investment involved, since only one-fifth of the growth will be required to balance the investment in the case of the electrification of the existing road against the investment in an entirely new road.

There is this to be considered: One hour's time is about the limit that a man will travel regularly to his work. The surface street cars go out this far at present. There is little more from them to be hoped for. The distance which they cover, beyond a certain point, is not determined by the speed they can make. They are capable of making better speed now than can be utilized. What holds them down is the necessity of passing across numerous streets and along streets encumbered with traffic. With increasing street traffic we shall expect the zone which they serve to constrict rather than expand. The railroads are independent of street crossings and of street traffic. The limit of the zone of one hour's travel merely depends upon the speed at which cars can be run. Ultimately, therefore, the extension of the city must hinge upon the ability of existing steam railroads to afford adequate local transportation.

For adequate local transportation facilities electrical working is the key. Because of its perfect control, higher and more even acceleration, higher speed, absence of switching, ability to haul any length of train as traffic demands and better ability to meet schedule so as to produce fewer disarrangements at terminals,— electrical working holds the advantage over steam.

Lastly, the desirability of electric traction to the public comes from the increased safety of travel which it offers. This comes because,—

1. The presence of smoke tends to obscure signals, approaching trains, and track defects. This is true more in foggy than in clear weather.

2. Convenient electrical power would mean its greater availability for lighting and for working mechanical safety-devices.

3. The operator on an electric locomotive has a better view of the track from his cab than the engineer on a steam locomotive, he has fewer devices to keep under his eye within the cab, and they are more nearly installed so as to be in line of vision with the track.

4. The operator on an electric locomotive is physically more comfortable than a locomotive engineer; consequently he should be more alert and his judgment clearer.

5. The handle controlling the supply of current to a motor car or

electric locomotive can be so arranged that turning it loose cuts the power from the motors. Thus, in case of a motorman losing his head in the face of an impending collision or derailment, the power will be automatically shut off by his letting go of the lever. This is used in the New York subway cars.

6. With electrical working, it is possible to arrange the block system so that a train's running into a closed block will automatically cut the power from that block and bring all trains within it to a standstill. This arrangement has been adopted on the Valtellina line in Italy. The Boston Elevated is equipped with a device which cuts the power from a train and applies the air-brakes when a train runs into a closed block.

7. With an electrical system, in the case of the discovery of an error in train despatching or a disregard of orders, it is possible to avert disaster by cutting off the current from the entire line. A report of such action has come in the case of a street railway. The New York, New Haven & Hartford has switches in the signal-towers which come at the end of line sections, whereby the power can be cut off at the signal-tower from a train which enters a closed block.

When we come to ask what electrification means to the railroads, we find that its desirability or undesirability from a railroad point of view, becomes almost entirely a question of economics. It is either a question of saving money or of making more money. It is believed that it will mean both in a good many cases.

Certain savings in operation are possible from electrical working over the costs under steam working. It becomes merely a question as to whether the economies will balance capital and maintenance charges upon the additional outlay involved. This, in turn, becomes a question of whether there is traffic density sufficient for the cumulative saving to offset the fixed charges. These items vary, of course, with each railroad. Let us examine where these economies may be expected to be found.

The absence of smoke and dirt will result,—

1. In longer-lived furnishings and appurtenances, paint, varnish, etc., of equipment. This follows (*a*) because dirt and gases are hard upon the life of these materials; (*b*) because the process of cleaning them tends to wear.

2. Less expediture for cleaning and renovating equipment. The lessened cost of renovation follows from (1). The lessened cost of cleaning comes in two directions, (*a*) the dirt will be smaller in quantity;

(*b*) what there is will be easier to clean. Soot and kindred products cling tenaciously. To remove them with soap and water requires an excess of scrubbing. The British use kerosene or gasoline, since carbon is best put in suspension by a hydrocarbon oil. But these are rather good at dissolving pigments, so the paintwork suffers.

3. In a lessened cost of upkeep of stations and other buildings.

4. In longer-lived steel work of viaducts, terminal sheds, and other structures exposed to locomotive gases. Locomotive gases are peculiarly corrosive. A large part of this action is probably due to the contained sulphurous acid — arising from the combustion of the sulphur in the coal and the admixture of the sulphur dioxide with the moist steam of the exhaust. A striking instance of the effect of these gases was afforded by the Boylston Street bridge in Boston, over four main tracks of the Boston & Albany Railroad. This bridge was erected in 1888 and in 1907 an examination was made. A plank floor covered the floor beams and the bottom part of the trusses, and above this floor the bridge members were found to be of their original size. Below this floor the bridge had been exposed to the gases and an examination showed the metal to have disappeared to an average of ⅛″ on each exposed surface. Several steel eye-bar diagonals had lost 60% of their original section and some iron floor beam angles had lost their entire outstanding leg. Some diagonal bracing was corroded in two. The chemical effects were much more marked than the mechanical.

5. In an allowable working of equipment to a greater capacity, due to less time kept out of service for cleaning and renovation, and, due to the greater attractiveness, filling the coaches nearer to their capacity.

6. There will be less wanton damage to equipment by the public. To invite respect, usually meets with response. This is shown negatively in the case of smoking cars on the elevated railroads, as compared with the other cars of the train. They invite abuse and receive it.

There are large savings possible which come from the nature of the locomotive itself and its inherent method of working. The locomotive is a highly developed, wonderfully specialized, and admirably worked-out machine. It represents better than almost any other apparatus what can be done despite limitations. But it remains a compromise machine. Certain things could be done if it were not for weight; others if it were not for vibration; again, the permissible width is absolutely limited by gauge of track. So it comes that an electric system, with all of its opportunities for loss in generators, transmission lines, transforming apparatus, working conductors, and motors, is able to deliver power at the axle of the tractor at a less cost in operating expenses and in maintenance, because freedom from restrictions enables each link in the chain to be chosen of the highest type of efficiency.

Items which induce to such economy are (*a*) those which come from ability to use a better style of boiler-plant; (*b*) those which come from using a better type of prime mover; (*c*) changes for the better in operation afforded; and (*d*) those which come from the superior general characteristics of electric motor vehicles.

Under (*a*) we find:

1. A steam locomotive boiler has not so good a water circulation as the specially designed types of water-tube boilers, the pass of the hot gases is not sufficient to extract the maximum efficiency, it fouls easily, and must be worked at a rate higher than that which makes for efficiency.

2. The refinements applicable to stationary boilers to produce economies, are barred of application to locomotives. These take the form of devices to secure even firing, to regulate air supply, to insure combustion, and to utilize the heat of uptake gases and condensed water. They comprise variously such items as automatic stokers, specially designed furnaces, baffles, superheaters, draft apparatus and air heaters, and feed water heaters. Their use is precluded because of space limitations or else because their cost is so high that the saving they would effect would not balance fixed charges upon the investment. As their cost per unit of capacity decreases with size, their use on power-plant boilers allows a net financial saving. This also appears true of certain of them (such as superheaters) on very large locomotives. The evaporation efficiency of locomotives as compared with stationary boilers, is as seven to ten, according to Mr. W. S. Murray as quoted in the Street Railway Journal of November 16, 1907.

3. The small surface of water area from which the steam is to rise, the intensity with which it is worked, the impure water which a locomotive boiler is more liable to get, the lurching of a locomotive under way, and the intermittent demand, all tend to produce priming in a locomotive boiler. In addition to the thermal waste involved in the passage over and going to waste of water heated just up to the steaming point, water primed over produces a mechanical loss disproportionate to its ratio to the volume of steam which brings it over. In the operation of engines where priming is bad, it is a common thing to see the engine slow down several revolutions while working the water through.

Besides the direct loss, priming runs up the repair bill. It is responsible for most of the broken piston rods, smashed cylinder heads and like accidents. In a year's observation of the steam-engine accidents which came to the largest engine builder in the country, we found no case of cylinder or piston smash-up which was not due to water in the cylinder. Again, on marine engines we have found the coveted glass-smooth polish of a cylinder ruined and the cylinder wall granulated by a few hours' running with the boilers priming.

4. The locomotive boiler, compared with other types, presents rather a hard proposition from the standpoint of upkeep and repair. It violates the canons of boiler design that every portion should be readily accessible for inspection, for cleaning, and for repairs. It has short turns, sharp corners, and large flat surfaces — all of which are bad from a standpoint of stress distribution and from that of facility and cheapness of repair. It has screwed stays and these exposed to the severest local action. The scale tends to stop up the water-legs where the flame action is concentrated. These characteristics make the boiler the weak part of the unit. Unfortunately, when the boiler goes wrong, the whole locomotive must be sent to the shop and taken out of service — and, in many cases, partly dismantled. Dismantling machinery nearly always entails minor expenses of repairs and adjustment. Repairs of an electric locomotive or motor car usually entail the dropping out of the motor truck or motor axle and replacing it with a good one — the machine remaining in service. (This follows because the weak point of such machines is the armature of the motor.) In the case of minor repairs several hours must elapse between drawing out the fires and emptying out the boiler and its becoming cool enough to allow the boiler to be worked upon,— while the motor armature becomes available upon shutting off the current. A lessened repair cost also comes from the greater accessibility of the motor parts.

Under (*b*) we find:

1. The type of engine which must be chosen for a locomotive is the least desirable type from an economic point of view. The engine employed is a short-stroke, high-piston-speed, slide-valve, throttling-regulating, hand-controlled engine. As opposed to long-stroke, slow-running, load-controlled, Corliss engines available for a central power-house, they are wasteful. In the case of simple, non-condensing engines, worked to advantage, the water consumption per 1 h. p. hour would stand somewhere at 36 for the locomotive type against 24 for the Corliss engine. With the further availment of compound condensing working the dis-

crepancy becomes greater. In addition, there is available for the power-house, further reduction in fuel consumption by the use of steam turbines or internal combustion engines.

2. The use of compound engines is largely restricted in a locomotive. The normal velocity of the flow of steam in a compound engine is lower than in a simple engine. (Locomotive piston-speeds are already so high that the admission line on indicator cards for locomotive cylinders always slants down.) We should expect, therefore, to find that to realize its maximum efficiency, a compound locomotive would require slower working than a simple locomotive. After the Santa Fe put their "900" class in service on the mountain division, we were told by the engineers who ran them, that they were "steam eaters" when you tried to speed them up. Mr. Quereau's figures of the indicated water consumption of single and compound locomotives at varying speeds, as given in Kent, bear this out. They follow:

Two-Cylinder Compounds			Single Expansion		
Revolutions	Speed m. p. h.	Water 1 h.-p. hr.	Revolutions	Speed m. p. h.	Water 1 h.-p. hr.
100 to 150	21 to 31	18.33	151	31	21.70
150 to 200	31 to 41	18.90	219	45	20.91
200 to 250	41 to 51	19.70	253	52	20.52
250 to 275	51 to 56	21.40	307	63	20.23
			321	66	20.01

The statement is made that the C. B. & Q. two-cylinder compound, which was about 30% less economical than simple engines of the same class when tested in passenger service, has since been shown to be 15% more economical in freight service.

A railroad cannot sacrifice speed to economy except in freight service. Hence, the field of compound locomotives would appear limited. Furthermore, departure from a single-designed running condition leads to unbalancing of the cylinders with its train of repairs. That operating conditions interfere with the expected economies of compound engines being realized in actual railway service, or else that their maintenance requires undue attention, is shown by the fact that the current Interstate Commerce Commission report shows the number of compound locomotives in use in the United States to be decreasing, while the number of simple locomotives maintains its annual rate of increase.

The saving of compound over simple working is best brought out by obtainable water-consumption guarantees for small Corliss engines. Twenty-four pounds can be obtained for the simple engine and eighteen for a compound engine of the same capacity.

3. Vacuum working is precluded in a locomotive. The use of a condenser in a stationary engine gives results varying with the conditions, but the saving effected will come somewhere around 35%, for which an outlay of 2% to 3% is expended for running the pumps connected with the condenser.

4. As a small engine, the locomotive engine possesses the inherent defects of such, which go to decrease efficiency. These, as compared with large engines, are increased surfaces presented for radiative losses per unit of power, increased clearance percentage, increased mechanical friction, increased skin friction of steam against the walls of pipes and passages and larger possibilities of loss through leaks and drains. Thus the coal per h.-p. hour in a simple, non-condensing, slide-valve engine decreases from 12 pounds in the case of a 5 h.-p. engine, to 8 pounds with a 100 h.-p. one.

Merely the substitution of the more efficient apparatus in the central power-house would lead us to expect the coal consumption in the power-house to be less than one-half that of the locomotive per h.-p. developed. Take Mr. Quereau's figures quoted above. They run about 20 pounds of water per 1 h.-p. hour. Allow 10% discrepancy between indicated consumption and actual consumption, and this figure becomes 22 pounds.

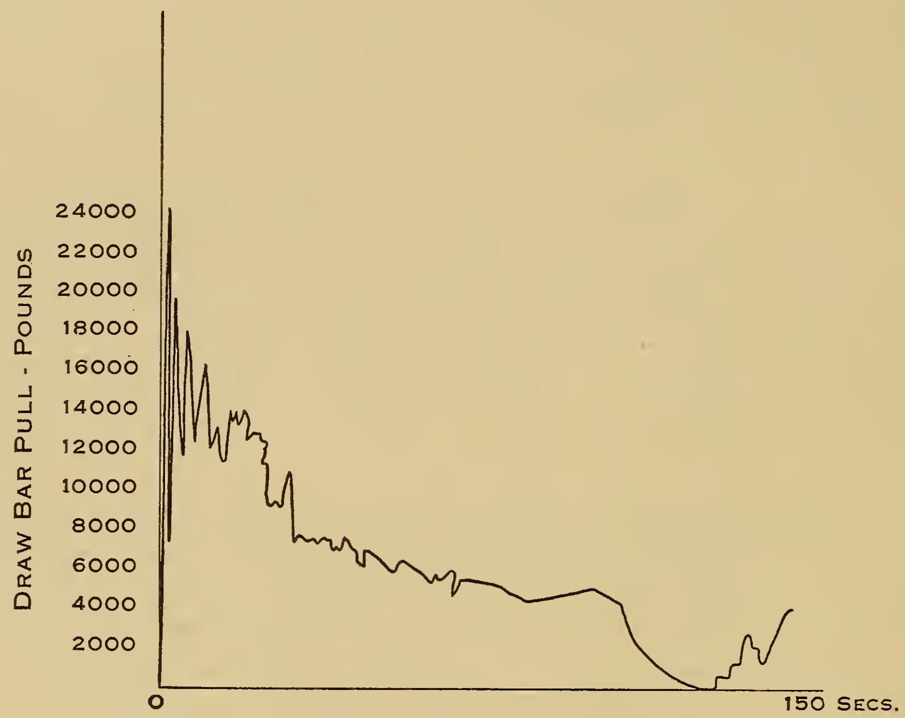
Around 12 pounds is easily secured at modern power-stations on test. (The Subway showed 11.96; the Waterside Edison plant 12.16; Cincinnati showed 12.28; the larger turbine tests give under 12; the South Side Elevated vertical engines were guaranteed at 12.5.) Since the evaporative efficiency of the boilers stood as 7 to 10, we should expect the coal consumption of the locomotive to be $\frac{22}{12} \times \frac{10}{7} = 2.65$ times that of the power-plant as the very smallest figure. Certain factors in operation which cause the power-plant engine to approach closely its test performance whilst in everyday use, and cause the locomotive to diverge therefrom, will increase this in the neighborhood of 50%, or the power-house consumption will be about one-quarter that of the locomotive per h. p. developed. Allowing 90% engine efficiency, 92% generator efficiency, 97% for high-tension line, 97% for transformer efficiency, 92% for rotaries, 95% for third rail, and 80% for motors, —gives an overall efficiency of 54.47% in applying our power to the axles. Thus we may expect that for every h. p. applied to the axles, 4×54.47, or rather more than two pounds of coal, will be used for steam-locomotive traction against one for electric traction. Mr. W. S. Murray estimates the coal consumption of the New York, New

Haven & Hartford railway (of which road he is the electrical engineer) as follows:

Trains	Tons Coal Steam	Tons Coal Electric
Express	57,477	29,870
Local Express	58,300	28,600
Freight	187,844	139,010

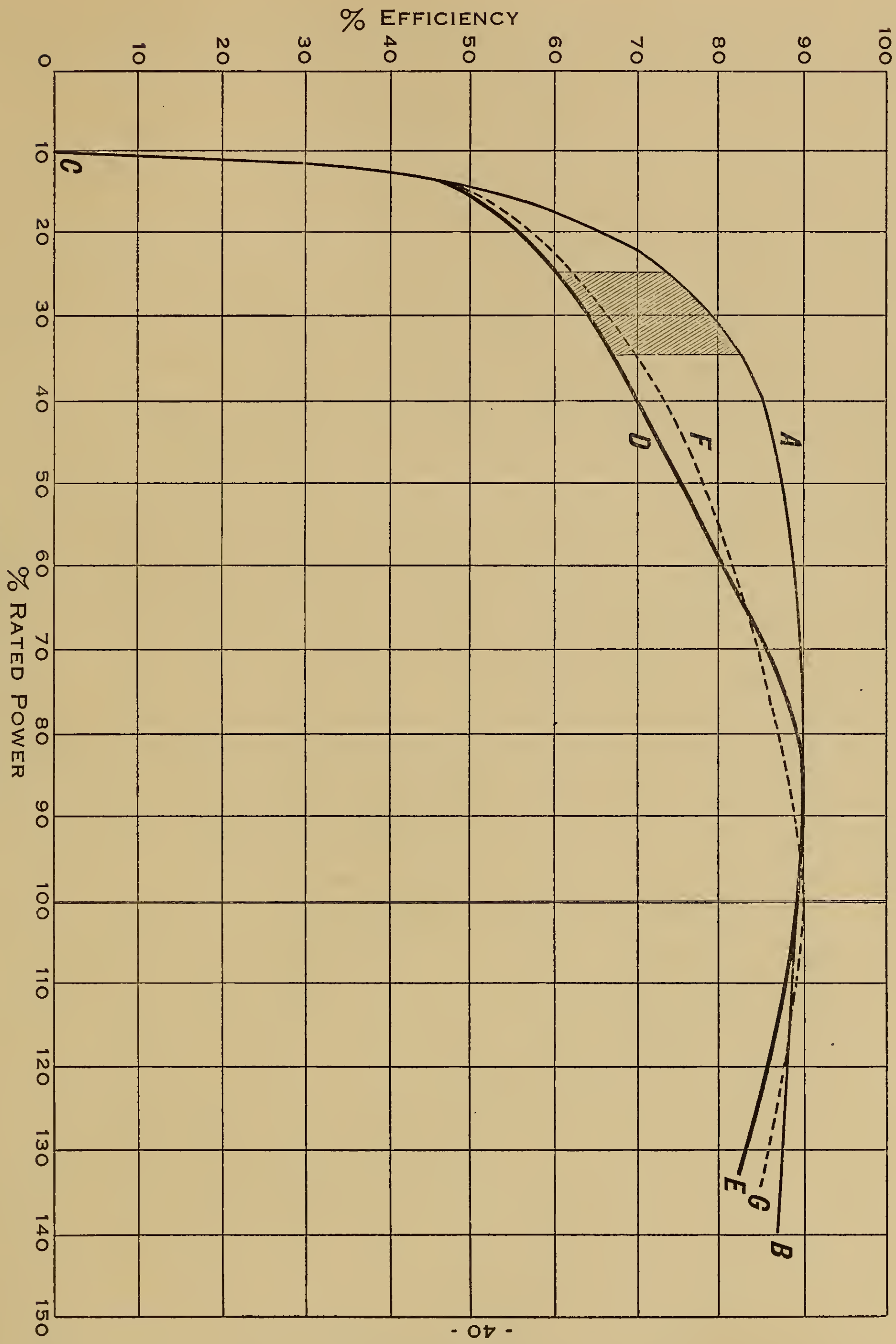
Under (*c*) we find:

1. The load on the power-house engines will be steady, while that on the steam locomotive is continually and suddenly fluctuating between large limits. The tendency for a number of electric locomotives



DRAW-BAR PULL—STEAM LOCOMOTIVE

or motor cars out on the line will be to equalize the fluctuations on the power-house engines — one will be drawing a maximum supply while another will be requiring very little current; at the most, the increment of several hundred h. p. from an individual, unbalanced train-starting load will produce a very small percentage variation upon the load of several thousand h. p. carried on the power-house engines, while on the individual steam locomotive such increment means a variation of two to three hundred per cent beyond the normal power requirement. Above is given a sketch reproductive of the dynamometer record of draw-bar pull (indicative of power developed), of a steam locomotive in the tests made for the New York Central by Messrs. Arnold and Potter in the preliminary electrification investigation for



EFFICIENCY CURVES

that road. (Published in the Proceedings American Institute Electrical Engineers, June 19, 1902.) This shows the fluctuation on a short run. While the load on the power-house engines will vary from hour to hour, it will be a gradual variation and, since the number of trains, their schedule and their probable weight will be known, the variations of this load can be determined beforehand and the number and size of engines running at the power-house will be so adjusted as to insure the power-house engines running at approximately their point of most economical performance. The difference in efficiency in working an engine at fractional or overload and working it at designed load is shown in the curves on page 63, where C. D. E. is a curve plotted from the guarantees given by the builders for a small Corliss engine, while C. F. G. represents the test performance of a Westinghouse Parsons turbine at the New York Subway plant. Both are plotted from steam consumption with the point of maximum efficiency reckoned as 90% efficiency and as 100% load. That they represent *steam* consumption should be borne in mind. Curves of *coal* consumption would make a still further unfavorable showing at points of largely reduced load or large overload. This is true because of the drop in boiler efficiency at overload because of crowding, and at light loads because of the increase in proportionate effect of losses which are fairly constant, i. e., radiation, coal dropped through grate bars and lost with ashes, stand-by losses, etc.

Of course, upon the individual motor car or electric locomotive, the percentage variation in power demand will be somewhere near (but not exactly, because of more even torque upon the axles) the same as upon a steam locomotive. But it is so happens that there is a wide variation in the efficiency of any steam engine (and a steam locomotive is a steam engine) between rated load working and working at underload or overload, while the efficiency of a motor remains fairly constant between wide limits. The curve C. A. B. in the diagram represents the efficiency of a railway motor. Owing to the large demand for power in accelerating, any tractive vehicle (be it steam or electric) must ordinarily run at one-quarter to one-third of its rated power. In the diagram, the shaded area represents this range and the difference in efficiency is apparent. (The engine is a Corliss engine and will regulate better and show a better fractional load efficiency than a steam locomotive's engine.)

2. The lessening of the number of points at which aggravation of troubles may occur, the better physical conditions of operation, and the greater facility for observation and repair of apparatus, which are afforded by electrical working, will result,— first, in a lessened maintenance charge for equipment; second, in a nearer approach of working performance of electrical apparatus to test performance than in the case of steam locomotives; third, in less dead time for repairs.

Simple wear of moving parts is probably the smallest item leading to repair bills in steam engines and the severer service of steam locomotives makes theirs an aggravated case. A little trouble developes in a steam locomotive while underway — it is a small affair, but it cannot be seen or attended to on the road, for the engine must be kept running; at the end of the run it has grown to a disablement. Thus, a stuffing-box begins to blow, a couple of turns is given the nuts, the packing burns, and a cut rod results; or a loose cross-head wedge gradually jars out and the cylinder is wrecked. This same aggravation exists in a measure in electric locomotives, but a good many of the aggravating initial causes are reduced. The primary motor is rotary instead of reciprocal, which reduces purely local stresses on parts; which reduces the total jar of the tractor trucks and body as a whole; and which decreases the superposition of local stresses upon general stresses in such manner as to be alternately in and out of phase and to lead to a wider stress variation with quicker consequential failure of parts. There are no parts of the electric motor which require the confining of a hot vapor under pressure; mechanical injury to the confining medium bringing a rending action. The reduction in vibration of parts under stress minimizes the ability of these parts to assume positions not contemplated in their design and which lead to their subjection to unsafe loads with consequent failure. The interdependency of electric motor parts is less than that of steam locomotive engine and boiler parts. A local injury is more liable to remain localized.

The wider range in temperature of steam locomotive parts tends to bring up the repair bills. This affects the engine as well as the boiler — the expenses chargeable to the latter's maintenance being eliminated with electric locomotives. With electric working there should be less dirt and that which does come has less access to working parts, due to the enclosure of motor and bearings.

Of course, with an electrical system there will be steam engines (or turbines) in the power-house, and steam boilers, just as on locomotives — with their chances for developing broken parts, leaky glands, split boiler tubes and other troubles which lead to maintenance charges and to a departure from test efficiency. Each power-house unit, however, will displace a score of steam-locomotive units on the road, and the number of parts liable to develop such faults will be reduced in proportion. The units will be subject to no shock or disturbance and will be shielded from all external contributing causes of trouble, the current practice of keeping a spare unit on hand will allow trouble to be repaired before it becomes aggravated, the accessibility of all parts will insure their adequate attention as well as their prompt repair, and the responsibilty of the man in charge of their operation and for their maintenance as well, will also lead to timely measures being taken. How small this maintenance becomes is shown by the distribution of operating expenses of electric roads taken from the census report. Maintenance of steam plant is credited with 9-10 of 1% of the operating expenses and of electric plant with 6-10 of 1%, or a total 1.5% of operating expenses or 9-10 of 1% of gross income. From the table of k. w.-hour costs for power-house disbursements given in Marechal's "Chemins de fer électriques," the following table is made up, giving the percentage of k. w.-hour costs charged to power-house maintenance and running repairs, *together with oil, waste*, etc.

Baltimore	10%
West Side, Chicago	30%*
Boston Elevated	40%*
Aurora, Elgin & Chicago	9%
Indianapolis	16%
Paris Metropolitan	20%*

Those marked with an asterisk are evidently arbitrary since there is an evident common divisor entering each component making up the total cost.

The following percentages of expenditures for material and supplies chargeable to the maintenance and repairs of the European stations, are calculated from Parshall and Hobart ("Electrical Railway Engineering"):

Glasgow	12.8%
London	8 %
Dublin	8.2%

It being reasoned that the maintenance and repair of electrically-propelled vehicles will be less than that of steam-propelled ones, let us examine actual results.

Taking the 1907 report of the Illinois Railroad and Warehouse Commission, and calculating from the total operating expenses, the operating expenses per car mile, and the amount of operating cxpenses charged to maintenance of equipment, we find the following values for maintenance per car mile on electric third-rail roads,—

Aurora, Elgin & Chicago	1.38 cents per car mile.
Chicago & Oak Park Elevated	1.02 cents per car mile.
Metropolitan Elevated	1.55 cents per car mile.
Northwestern Elevated	1.90 cents per car mile.
South Side Elevated	1.41 cents per car mile.

From the Massachusetts Railroad Commission Report, we calculate for the same, Boston Elevated 1.84 cents per car mile.

Mr. Potter ("Developments of Electric Traction," before New York Railroad Club, January 20, 1905, — quoted in Street Railway Journal), gives the maintenance of electrical equipment on the Manhattan Elevated cars as ¼ cent per car mile.

Cserhati states that on the Valtellina, from July 1, 1903, to June 30, 1904, the maintenance and repair of rolling stock, including electrical equipment and mechanical parts, was 1.38 cents per *locomotive* mile.

On the Paris-Orleans line, the maintenance and repairs per *train* mile, according to M. Dubois are 2.5 cents per *train* mile; and on the Paris-Versailles (largely multiple-unit trains) 2.4 cents per *train* mile.

On the Mersey road, according to Dawson, the repairs and renewals of "wagons and carriages" per *train* mile were reduced from 3.498 cents to 2.150 cents by changing from steam to electrical working.

A. H. Armstrong (lecture before Brooklyn Polytechnic Institute, December 5, 1905) estimated the expense per car mile of motor cars, including maintenance and repairs, inspection of car bodies and trucks, painting, varnishing, etc., at 1 cent per car mile.

Dawson ("Engineering and Electric Traction Pocket Book") estimates similarly .961 cent per car mile.

For electric-locomotive repairs, Mr. W. S. Murray is quoted in the technical press as estimating for the New Haven, 2.5 cents per *train* mile.

The expenses for a New York Central electric locomotive, for inspection and repairs, on a 100,000-mile test run, were 1.26 cents per *train* mile.

The St. Louis & Belleville Electric Railway, in a letter to the General Electric Company stated, regarding their electric locomotives, that for an average working of 312 days per year hauling coal and miscellaneous freight, averaging about ten hours per day, the electric-locomotive repairs (for the locomotive performing this work), were a little over $88.00.

The International Railway Company, in a letter to the General Electric Company, stated that records covering the cost of maintenance of two electric locomotives for three years and eight months, showed a total of $1257.56, or an average of $342.96 per annum. This is $171.48 per annum per locomotive. The letter states that the locomotives make an average of 100 miles per day for seven days in the week and are out of commission for repairs about five days a year. This figures less than ½ cent per *locomotive* mile.

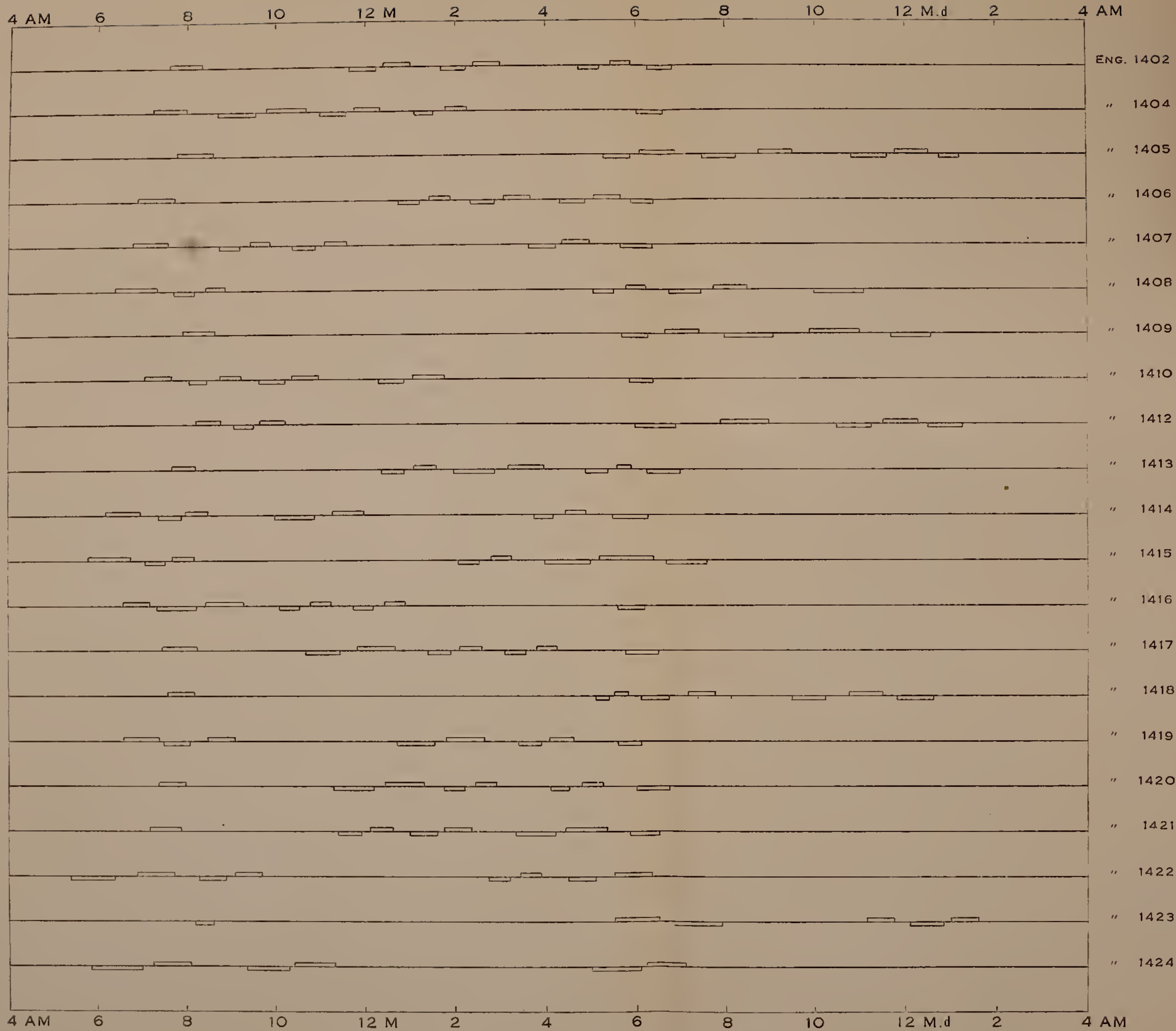
Byers (Railway Economics) gives the repair cost of *steam* railroad passenger cars per car mile for 1903, as follows:

B. & O.	.91 cents per car mile.
P. R. R.	2.06 cents per car mile.
P. R. R. Western Lines, N. W. System	1.72 cents per car mile.
P. R. R. Western Lines, S. W. System	1.40 cents per car mile.
B. & M.	1.55 cents per car mile.
New Haven	1.44 cents per car mile.
D. & R. G.	.88 cents per car mile.
Hocking Valley	1.56 cents per car mile.
St. L. & S. W.	1.29 cents per car mile.
C. & O.	1.23 cents per car mile.
N. & W.	1.60 cents per car mile.
C. & G. W.	.86 cents per car mile.
I. C.	1.04 cents per car mile.
C. R. R. of N. J.	1.11 cents per car mile.
M. St. P. & S. S. M.	1.00 cents per car mile.
Erie	1.79 cents per car mile.
L. V.	2.00 cents per car mile.
C. I. & L.	1.87 cents per car mile.
Southern	1.27 cents per car mile.
A. T. & S. F.	.90 cents per car mile.

An examination of the data afforded leads to the conclusion that the increased cleanliness, less severe working conditions and lessened wear and tear of electrical working will effect so large a saving in coach maintenance and repair, that an electrically-propelled multiple-unit train will entail about the same expense for upkeep of both coaches and electrical equipment combined, as is expended for the upkeep of coaches alone in steam working. Remembering that the average train for suburban and passenger service is somewhere around a four-car train, in the case of a train drawn by an electric locomotive, it would also seem true that enough will be saved in the upkeep of coaches to pay for the upkeep of electric locomotives. In the case of freight trains adequate data is not available.

It would thus be indicated that, in the case of a complete conversion, the entire steam-locomotive repair bill could be saved as a net saving toward offsetting the fixed charges on electrification.

3. There is a good deal of time that the steam locomotive is burning coal and rendering no return. Thus, when the steam locomotive is stopped, the fire goes on just the same. Most of the heat developed goes to waste. The attached diagram gives a graphic representation of the employment of 22 suburban locomotives observed on the Illinois Central, during 24 hours. The spaces outlined above the long lines



HOURS IN SERVICE—I. C. SUBURBAN LOCOMOTIVES

represent north-bound runs and the spaces underneath, south-bound runs, — while the unoccupied portions of the line represent the time idle during 24 hours. These constituted about one-half of the locomotives in service on the Illinois Central suburban runs during this day, and represent the lowest 22 numbers on the line, the other locomotives being idle about the same proportion of time as those shown.

In the electrical power-house, the stopping of a motor does not mean the ceasing to draw steam from a boiler, for there are other motors which impose their load partly on the boiler,—it causes a slight change in the steaming rate instead of a reduction to almost nothing. There is a good deal of dead movement expended by the steam locomotive in going back and forth to coal chutes, water stations, cinder pits, etc., which burns coal without any monetary return. There is other dead movement (which the electric locomotive or motor car will obviate), due to the necessity of switching around trains at terminals and due to less mobility of the steam locomotive. With the steam locomotive, a cold boiler and engine plant must be heated each morning and a warm boiler allowed to grow cold at night. Where no effort is made to utilize the heat left in the boiler at night, the amount lost is approximately the coal needed to raise steam each morning (together with the attendant labor). Where an effort is made to utilize the heat, unit efficiency cannot be obtained. Even with the maximum possible results, there will be lost the heat contained in the iron of the locomotive. Against these, an electric locomotive draws power when it runs and cuts it off when the necessity ceases; for the starting and stopping throughout the day, little alteration in the steaming of the power-house boilers is effected, — some boilers at the power-house are kept going day and night for weeks; the others are only shut down with the variations of requirement for the entire stretch of road and not the fluctuations of an individual motor.

4. The greater capability of electric tractors for service will enable the capital invested in them to be in service a larger proportion of the time, so that the greater interest charges thereon (from greater first cost) will be partly offset. There will be saved to usefulness for the electric machine the time lost by a steam locomotive in raising steam, the time in going back and forth to water tanks, fuel stations, etc., the time saved in switching and similar dead movement, the difference in time spent in shops for repairs by steam and electric locomotives. This latter, coupled with the instant availability for service of electric locomotives, will also allow of a smaller reserve number being kept on hand.

Mr. W. J. Wilgus (Proc. Am. Soc. Civ. Eng., March 18, 1908) gives some figures regarding the electric operation of the New York Central wherein is shown for the electric working under examination, a saving of

18% in dead time for repairs and inspection.
6% in locomotive ton-mileage in hauling service.
11% in locomotive ton-mileage in switching service.
18% in locomotive ton-mileage in road service.

Mr. W. S. Murray (Elec. Engineer, N. Y., N. H. & H. R. R.) is credited in the Street Railway Journal of November 16, 1907, with the statement that the electric locomotives do yard switching in one-half the time of steam locomotives.

The Street Railway Journal (October 5, 1907), speaking of the operation of the New York Central's New York terminal by electricity, said that the total number of movements in the yard, July 2, 1907, not only for regular trains but also for switching, showed a decrease of about 35%. On the same day delays were decreased from a total of 443 minutes per day to 122 minutes.

Steam locomotives are dead for repairs about one month in the year, or, say 8% of the time. Mr. Brinckerhoff has published a statement to the effect that the Metropolitan Elevated (Chicago) cars, during 1905–1906, were available for service 97% of the time, each working 3,500 miles per month. With a slightly smaller mileage the Buffalo & Lockport electric locomotives are out of commission for repairs five days in the year, or 1.37%.

On the Valtellina, according to Bela Valatin, 35,120 miles per annum are made with each electric vehicle, while the average steam locomotive mileage was only 17,213. An examination of the motor cars after a 100,000-mile period of service, disclosed no necessity for changing bearings or renewing bushings.

The New York subway cars are overhauled when they make an average mileage of 65,000.

On the Brooklyn Rapid Transit Elevated line, the annual train mileage per locomotive under steam in 1898 was 37,110 against an annual train-mileage of 40,140 in 1905 per motor car under electric operation.

How electric traction makes the full equipment available in an emergency was shown by the Northeastern Railway of England in 1904, when the British Channel squadron dropped into Newcastle, and, because of the rush of crowds to see the spectacle, put a sudden and extraordinary demand upon their electrified section. The first day, 86 out of 89 cars owned were run. The second day 89 cars (the entire equipment) were run from 5 P. M. to 11 P. M., and not a single breakdown was experienced.

5. Some saving in train labor will be effected by electric operation. The labor of the firemen will be saved. The dispensing of the second man on the motor vehicle seems to be open to argument. On the multiple-unit trains propelled by motor cars in the train, such as would be applicable to suburban service, we believe the dispensing of the motorman is practically universal. In electric-locomotive propulsion, practice is divided. The Baltimore & Ohio, for instance, is running electric locomotives through the Baltimore tunnel with no helper for the motorman. The trains into the New York terminal carry a helper on the electric locomotive. After the service has been longer continued he may be taken off — that remains to be seen. Except as an additional lookout, his presence seems unnecessary. With the controller of the locomotive equipped with the so-called "dead man's handle," in case of any disablement of the motorman the spring would throw the handle to the "off" position and the locomotive be brought to a stop. An excellent way of working is carried out on the Valtellina road in Italy. The locomotive motorman has no helper, but the conductor is required to familiarize himself with the working of the locomotive so as to be able to bring the train to its destination in case the motorman becomes ill or otherwise incapacitated. He is even required to change places with the motorman at times. Heft's figures on train labor per train mile on certain electrified branches of the New York, New Haven & Hartford railroad are as follows:

Berlin Branch	$0.18
Highland Division	0.027
Nantasket Beach Branch	0.0829
New Canaan Branch	0.063
Steam Operation (about)	0.12

That the railroad, through electrification, would lose the services of its firemen whom it had trained to its employ, would not necessarily follow. A few of them would be required for the electrical power-house. The electrification of a terminal would take considerable time and a good many who are firemen at its inception will pass to the grade of engineer and qualify for running electric locomotives by the time of its completion. In the elapsed time, others (because of their right to preference through their years of service) would have a chance to be taken care of through the regularly occurring vacancies at other points than Chicago. Also, a considerable augmentation of suburban traffic is to be expected and the present firemen on terminal service will be needed to act as motormen. That they will want it, is probable, as the work is cleaner and lighter than firing a steam locomotive. That it would be preferable to have the present engineers and firemen qualify to run the electric trains is generally undisputed, since they are familiar with the track and with existing operating conditions and train rules.

6. A certain proportion of the shrinkage in coal between the car and the boiler grate would be saved by electrical working. Every handling means a small percentage loss. With the coal delivered at the power-house and stored under cover above the boilers, this chance of loss is minimized.

A saving in fuel-handling cost will ensue from electrical working, since the coal consumption will be cut in half. Where there is a further saving lies in the fact that modern power-plants handle their coal and ashes by specially designed conveying machinery. The coal is dumped or shovelled into a hopper underneath the car; belt or bucket conveyors convey it into the crusher and to a bin above the boilers. It is fed by gravity upon the grates. The ashes drop into pockets beneath the boilers, whence they are tapped to a conveyor which delivers them into a hopper above the coal cars. When the coal in a car is unloaded, the ashes are dropped into it from the hopper above. It is about as cheap a way to handle coal and ashes as can be devised. Locomotive coaling varies from shooting the coal to the tender from pockets filled from elevated tracks to moving it several times from place to place by shovelling. In the smaller stations the bulk of the crew's time must necessarily be put in to no useful purpose. (At such a station as the one under the Randolph Street viaduct over the Illinois Central tracks). Taking the stations collectively, allowing for lost time, labor, superintendence, tools, and repair of stations, interest on plant investment, and dead mileage saved, it would seem that 50 cents per ton would be a fair overall allowance for the expense in Chicago of unloading coal and placing it upon the tender of the locomotive.

7. A large proportion of the round-house labor other than that occupied in coaling and ash removal, would be released by electrical operation. This would come, first, because the substitution of motor cars for locomotives in suburban service and the greater mileage efficiency of electric locomotives, would decrease the number of units requiring attention; second, because the units would be less dirty and the dirt more readily removed; third, because many of the parts requir-

Courtesy Westinghouse Electric & Mfg. Co.

New York, New Haven & Hartford Railroad — Typical Catenary Line Construction on Tangent — Alternating-Current Single-Phase Installation.

ing daily attention on a steam locomotive would have no equivalent part in an electric locomotive; and fourth, certain parts requiring daily attention in a steam locomotive would be replaced by equivalent parts in an electric locomotive requiring only occasional attention.

8. The cost of operation of water stations (amounting to about 8–10 cent per train mile) would be entirely saved by electric working.

9. The interest charges upon investment in water and fuel stations and the difference in round-house plant required, should be deducted from the charge against electrical operation. While such plants are now on hand this would not effect an absolute saving of this amount. As the terminal demands in Chicago increase, an absolute saving of the interest charges upon the amounts which it would be necessary to expend for their extension, but for electrification, would be had. After a reasonable time for their extinction, the capital amounts at present invested would also afford an absolute amount passed to saving on interest charges. As many of the round-houses and plants of this character about Chicago are fifteen or twenty years old, the sinking funds carried against them should have already extinguished much of their value. Of course, a portion of these interest savings will appear as charges against coal, ash, and water plant inside the power-house, but its better shielding from the weather and its lessened first cost through reduction in required capacity and centralization, will make interest and maintenance charges less. These will appear in the general power-house charge so, for purposes of calculation, the entire amount now charged under steam operation may be set in the column of savings.

10. The greater simplicity in the care and repair of the electrical locomotive (with the exception of its motor and control apparatus) will possibly enable certain of the maintenance work to be done by ordinary labor which now requires skilled labor. This will have its value as insurance if not as a positive saving, for it is easier to secure common labor, at times when labor is at a premium, than skilled labor. It is to be reasonably expected that (the work being cleaner) greater returns will be secured from labor employed. Between a clean job and a dirty one, the better class of workmen will choose the clean one — provided the pay is equal. A better class of workmen will be attracted. Further, put an efficient man in a dirty place to work — physical discomfort mars his efficiency, revulsion saps his conscientiousness. So we should expect for the railroad that (*a*) their better class of laborers and workmen around the terminal should increase their efficiency;

(*b*) a sufficient number of desirable men should be attracted to allow of weeding out the undesirable ones.

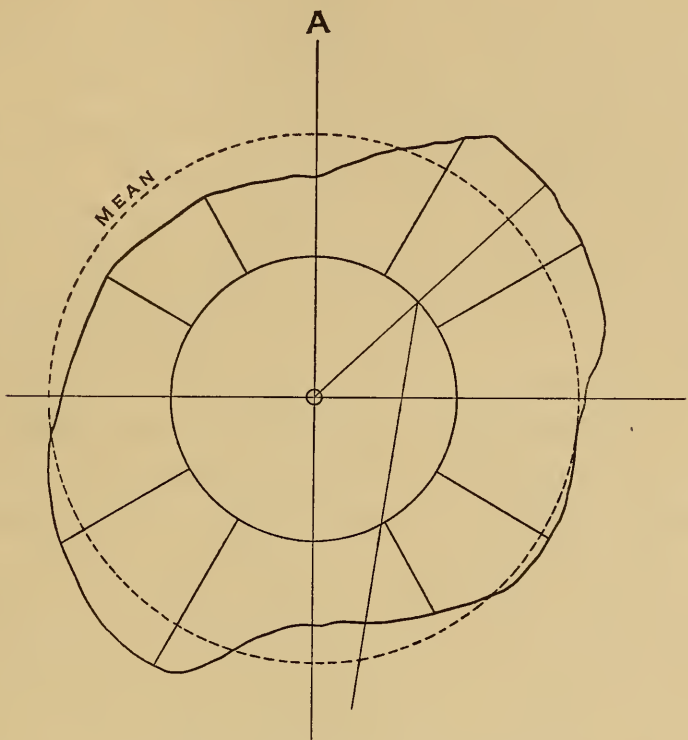
11. Very cold weather interferes with steam-train schedules, thereby upsetting terminal arrangements, and, besides, causing public dissatisfaction, running up bills for extra labor and incidental expenses. This comes from the chilling of the boiler and of the air supplied to it to such an extent that speed cannot be held. As the electric locomotive or motor car has no boiler, and the cooler the motors are kept the better, the abnormally cold weather becomes an advantage rather than otherwise. Thus, in the very severe winter of 1904–1905, the steam suburban trains into the Grand Central station at New York came into the terminal so habitually late that public indignation was aroused and the press set up an insistent clamor. The elevated railway, electrically run, maintained its service. In response to complaint lodged last winter of the very poor service on the New London & Northern operated by the Central Vermont Railway Company, the Central Vermont company gave as one of their reasons for the delays, in an official document to the Connecticut Railway Commissioners "The extreme cold weather and other conditions arising from the severe winter, all of which had much congested its traffic."

Sleet and snow will affect the electric locomotive as well as the steam one.

Under (*d*) we find:

1. Per pound weight on drivers and per unit horse-power supplied, the electric motor vehicle gives a greater tractive effort than the steam locomotive. This is because of the even torque throughout a revolution, maintained by an electric motor. It requires more effort to start locomotive drive-wheels slipping upon the rails than to maintain it. Consequently, the more uniform our torque, the higher our co-efficient of adhesion. The angularity of the connecting rod, the variation of pressure in the cylinder during the stroke, and the inertia of moving parts, make a large variation between the maximum and the mean crank effort exerted by a simple steam engine. The ratio is 1.5 to 2.5, depending upon circumstances. With high steam pressures, low cut-offs, short strokes, and high speeds, the maximum effort will exceed three times the mean effort. With two cylinders with crank-pins at right angles, as in a locomotive, the combined-crank-effort diagram will still show the maximum crank effort (or torque) to be 1¼ to 1½ times the mean. Owing to the multiplicity of coils in a motor armature, the torque curve thereof will exhibit a superposition of a multiplicity of

modified sine curves, each a fraction of a period in advance of the foregoing; the resultant curve being a series of wavelets of shallow depth and the ratio of maximum to mean being so near unity that it may be so considered for all practical purposes.



CRANK EFFORT DIAGRAM

The curve marked "A" above (taken from Urwin) exhibits (by the length of the intercept between inner circle and outer curve) variations in crank effort of a compound engine with cranks at 90 degrees. The sketch curve B C is a portion of a torque curve of a motor as it would be expected to appear, the number of convolutions being largest with the greatest number of coils in the armature.

MOTOR TORQUE

Because of the difference in torque characteristics, the electric locomotive can exert about 15% more tractive effort. Normally they are rated at 22 to 25% weight on drivers, following steam locomotive practice, but tests have developed as high as 35% adhesion.

2. The steam locomotive is compelled to haul a great deal of dead weight throughout the day, in the shape of tender, fuel and water, and weight of locomotive not carried on the drive-wheels. This forms a large proportion of the weight of the train in suburban service and an appreciable proportion in other kinds of service. The steam locomotive carries only 40 to 60% of its weight on the drivers and there is, thus, only this proportion available for tractive effort. In the case of multiple-unit trains, this being the form generally adopted for handling suburban traffic, the entire weight of electrical equipment is borne on the driving axles, so that every pound of weight in the train is available for traction. In addition, the motor vehicle has the same body as the trailing cars and is available for carrying passengers. In the case of through passenger trains, and freight trains, it is necessary to handle them with electric locomotives in an electrified system. While it is possible to carry the entire weight of the electric locomotive on motor axles and while this was at first advocated and a number of electric locomotives have been so constructed, it seems to be the consensus of opinion at present that it is necessary to design the under body of the locomotive somewhat similar to steam locomotives and sacrifice a portion of the tractive effort. It is evidently best to make the same provision as regards leading and trailing trucks, as has been found best in steam locomotive practice; otherwise, a tendency to "nosing" with consequent spread rails results and, for the purposes of steadiness and safety, it is necessary to sacrifice a portion of the theoretical advantages. At the same time, if no better disposition of the weight can be obtained than with the steam locomotive, we would still save the weight of the tender, amounting to from 40 to 70 tons.

Following is a table giving the general data of representative suburban locomotives used on American railways, taken from Engineering News, February 16, 1905:

Tank Locomotives for Suburban Traffic

Railways	Cen. Ry., N. J.	C. & E.	C., B. & Q.
Class....................	2–6–2	2–6–6	0–6–2
Tank....................	Side	Rear	Rear
Driving Wheels.........	5′ 3″	5′ 3″	4′ 9″
Front truck wheels......	3′	2′ 6″	......

Railways	Cen. Ry., N. J.	C. & E.	C., B. & Q.
Rear truck wheels	3′ 6″	2′ 6″	3′
Wheel-base, driving	14′	12′ 9″	14′ 4″
Wheel-base, total	31′ 8″	20′ 3″	22′ 5″
Total length	......	46′ 11½″	37′ 10″
Weight on drivers	129,000 lbs.	95,000 lbs.	94,000 lbs.
Weight on front truck	21,900 lbs.	14,000 lbs.	......
Weight on rear truck	39,000 lbs.	62,000 lbs.	19,000 lbs.
Weight total	189,900 lbs.	171,000 lbs.	113,000 lbs.
Cylinders	18 x 26 ins.	18 x 24 ins.	17 x 22 ins.
Valves	Slide	Slide	Slide
Boiler, diameter	4′ 10¾″	4′ 8″	4′ 3¼″
Boiler, pressure	200 lbs.	150 lbs.	160 lbs.
Fire-box	109 x 72 ins.	90 x 42 ins.	72 x 42 ins.
Tubes, number	249	247	194
Tubes, diameter	2″	2″	2″
Tubes, length	13′	11′	11′
Heat surface; tubes	1695 sq. ft.	1360 sq. ft.	980 sq. ft.
Heat surface; total	1834.6 sq. ft.	1484 sq. ft.	1064 sq. ft.
Grate area	54.5 sq. ft.	29.2 sq. ft.	21 sq. ft.
Water, gallons	3000	2450	1650
Coal, tons	5	5	2–½
Tractive power	22,700 lbs.	......	......

Railways	C., R. I. & P.	Ill. Cent.	Long Island
Class	2–6–6	2–4–6	2–6–2
Tank	Rear	Rear	Side
Driving wheels	5′ 3¾″	4′ 8½″	5′ 3″
Front truck wheels	2′ 6″	2′ 9″	3′
Rear truck wheels	2′ 9″	2′ 9″	3′
Wheel-base, driving	13′ 4″	6′ 10″	14′
Wheel-base, total	21′ 4″	32′ 7″	31′ 8″
Total length	49′ 7″	43′ ¾″	......
Weight on drivers	107,000 lbs.	72,000 lbs.	130,365 lbs.
Weight on front truck	19,700 lbs.	17,500 lbs.	23,910 lbs.
Weight on rear truck	68,000 lbs.	76,500 lbs.	34,540 lbs.
Weight, total	194,700 lbs.	166,000 lbs.	188,815 lbs.
Cylinders	18 x 24 ins.	17 x 24 ins.	18 x 26 ins.
Valves	Slide	Slide	Slide
Boiler, diameter	4′ 10″	4′ 9″	5′
Boiler, pressure	160 lbs.	150 lbs.	200 lbs.
Fire-box	101½ x 33 ins.	95$\frac{11}{16}$ x 34⅞ ins.	......
Tubes, number	240	200	249
Tubes, diameter	2 ins.	2 ins.	2 ins.
Tubes, length	11′ 1″	10′ 10″	13′
Heat surface; tubes	1226 sq. ft.	1134.40 sq. ft.	1684.0 sq. ft.
Heat surface; total	1384 sq. ft.	1250.83 sq. ft.	1821.4 sq. ft.
Grate area	23.26 sq. ft.	23.00 sq. ft.	54.5 sq. ft.
Water, gallons	2600	2500	2400
Coal, tons	4	6	5
Tractive power	......	16,570 lbs.	......

Railways	N. Y. Central	Phila. & Reading
Class	2–6–6	2–6–4
Tank	Rear	Rear
Driving wheels	5′ 3″	5′ 1⅝″
Front truck wheels	2′ 6″	2′ 6″
Rear truck wheels	2′ 6″	2′ 6″
Wheel-base driving	15′	12′ 6″
Wheel-base total	35′ 10″	30′ 9″
Total length	48′ 1½″	......
Weight on drivers	128,000 lbs.	120,860 lbs.
Weight on front truck	24,000 lbs.	19,120 lbs.
Weight on rear truck	64,000 lbs.	61,720 lbs.
Weight, total	216,000 lbs.	201,700 lbs.
Cylinders	20 x 24 ins.	20 x 24 ins.
Valves	Piston	Slide
Boiler, diameter	5′ 9″	5′ 6″
Boiler, pressure	200 lbs.	200 lbs.
Firebox	92⅝ x 88⅞ ins.	105 x 94 ins.
Tubes, number	365	447
Tubes, diameter	2 ins.	1¾ ins.
Tubes, length	12′	9″
Heat, surface; tubes	2275.0 sq. ft.	1825.5 sq. ft.
Heat surface; total	2458.0 " "	68.5 " "
Grate area	56.6 " "	68.5 " "
Water, gallons	3700	3000
Coal, tons	5	3¾
Tractive power	27,000 lbs.	28,000 lbs.

Take the case of the suburban service on the Illinois Central, which is familiar to most people around Chicago. The total weight of their suburban locomotive is 166,000 lbs., of which the weight on the drivers is 72,000 lbs., or only 43.5% of the weight is available for traction.

Take the case of the Woodlawn local trains which in general are composed each of two 65′ steel cars, seating 120 passengers and weighing 78,000 lbs. — the steam train weighs:

Locomotive	83 tons
Cars	78 "
Total	161 "

If we take the same car bodies and trucks and equip them with two General Electric 66-A motors to each car, we shall add about 10½ tons for the complete electrical equipment for each car, or 21 tons for the train, these motors having a rated horse-power of 500 and a tractive effort of 17,900 lbs. (which compares very closely to the 16,570 lbs.

tractive power of the locomotive) at 260 amperes input and 500 volts. The electric train will then weigh:

Coaches	78 tons	
Electrical equipment	21	"
Total	99	"

against 161 tons for steam, or only 61.5% of the weight hauled with the same seating capacity.

Take the case of four car trains such as run on the express service to South Chicago, Blue Island, etc., during the middle of the day. On these trains an ordinary suburban car is hauled, 51′ long, weighing 38,000 lbs., and seating 56 passengers. The steam train weighs

Coaches	4 x 19	76 tons	
Locomotive		83	"
Total		159	"

The electric train weighs

Coaches	4 x 19	76 tons	
Electrical equipment, 2 motor cars only		21	"
Total		97	"

or the electrical train of the same seating capacity weighs 61% of the steam train. Thus a substitution of electrical working on the Illinois Central suburban service would give the same passenger capacity and require the hauling of only three-fifths of the weight. As the Illinois Central suburban service has a daily mileage of about 3,500 train miles, there would be a daily ton-mileage haul saved on suburban service of 217,000 ton miles. The adoption of electricity would mean a power consumption of approximately two-thirds the present, or that, with the same power consumption, approximately 50% more trains could be run.

Take the case of trains requiring locomotive haulage. The Atlantic type of engine (New York Central 3,000), has a total weight of 160 tons, the weight of the engine alone being 100 tons and the weight on drivers 55 tons. The horse-power is 1,360 and a maximum tractive effort of 33,500 lbs.

In a Pacific-type locomotive, total weight 175 tons, the weight of the engine alone is 110 tons, the weight on the drivers 67 tons. The horse-power 1,640, maximum traction effort 27,500 lbs.

The New York Central's famous American-type engine No. 999, weighs 102 tons, the engine alone weighing 62 tons, and the weight on drivers being 42 tons.

The New York Central's electric locomotive weighs 94½ tons, of which 68½ tons is borne on the drivers. These engines are of 2,200 horse-power with a 3,300 horse-power overload capacity and a total maximum tractive effort of 33,000 lbs.

The electric locomotive is thus seen to be much lighter in total weight; in the case of the New York Central to have a larger proportion of total weight borne on the drivers; to have a higher horse-power and a very high maximum tractive effort.

If we take the case of an equivalent tractive effort of around 30,000 lbs. to correspond to the Pacific-type steam locomotive, we find the Paris-Orleans electric locomotive (so rated) weighs only 55 tons, or less than the weight of the tender of the Pacific-type locomotive. The electric locomotive also has less concentration of weight on each driving axle, owing to its even distribution of weight; in the case of the New York Central, the total number of pounds per driving axle being 47,000 for steam and 35,500 for the electric,— according to Mr. Wilgus.

In the case of a train of six standard coaches weighing 86,000 lbs. each, the weight of the steam train becomes

Coaches	258 tons
Locomotive	160 "
Total	418 "

and of the electric train:

Coaches	258 tons
Locomotive	94½ tons
Total	352½ "

or the electric train only weighs 84% of the weight of the steam train.

Take the case of one of the heavier trains run by the Illinois Central. Suppose that this train carries three baggage, mail, and express cars, a coach smoker, a day coach, a chair car, two Pullmans, and one diner. The total weight of the steam train would be:

6 Coaches are equivalent to	258 tons
3 Pullmans " " "	150 "
Locomotive	160 "
Total	568 "

and of the electric train

6 Coaches are equivalent to	258	tons
3 Pullmans " " "	150	"
Locomotive	94½	tons
Total	502½	"

or the electric train only weighs 88.5% of the steam train.

This reduction in weight induces toward less power consumption in two directions. In the first place, it makes the train of a given passenger capacity of less weight per passenger, and it also makes the train of a heavier weight per linear foot. Aspinall's experiments show that in the case of long freight trains of similar weight and similar speeds, the loaded and shorter train showed a greatly reduced tractive effort in pounds per ton weight of train required to move the train, over that required for the longer, empty train. In the case of suburban trains, in addition to getting rid of much of the weight of the locomotive, we should also get rid of a disproportionate consumption through doing away with the locomotive altogether. The head resistance of the train will, of course, be somewhere near the same, but a good many of the mechanical and other losses belonging to the locomotive, will be done away with. The large amount of power absorbed by the steam locomotive is brought out by Mr. Aspinall in his celebrated paper on train resistance. We quote him as follows:

"In order to see how much power the locomotive absorbed, as compared with the train, a certain number of experiments had been tried on the Lancashire & Yorkshire Railway, and it had been found that the ten-wheeled engine (No. 1392) absorbed 34% of the total horse-power. Mr. W. M. Smith (Proc. Inst. Mech. Engrs., 1898, p. 605) had given the results of his experiments as about 36% of the total horse-power; and Mr. Druitt Halpin had stated (Proc. Inst. Mech. Engrs., 1889, p. 150) that the Eastern Railway of France had found that the engine absorbed 57% of the total horse-power developed; while Dr. P. H. Dudley gave it at 55.6%, and Mr. Barbier at 48%. Probably 34% or 36% was about the right percentage, the other figures being much too high; at any rate, the experiments referred to in the paper rather pointed to that conclusion, though, of course, the actual figure depended upon the load behind the engine." (Aspinall, Proc. of Institution of Civil Engineers, 1901.)

3. The employment of electrical locomotives or of motor cars, permits of a larger interchangeability of parts and a more efficient hand-

ling of spares, than is at present possible. This comes because a great deal of electrical material is more or less alike and particularly because nearly all of the electrical parts do not have to depend so much upon closeness of fit as locomotive parts. Thus, in the majority of instances, a part may be renewed in an electrical machine simply by inserting the part as it comes from the manufacturer, while engine parts usually require more or less fitting and a worn part cannot be taken from one engine and put to working in another, as a general rule.

4. The higher mileage capacity allowable with electrical apparatus has already been touched upon.

5. Under electrical working, there is theoretically no limit to the train load which can be handled, except the draw-bars of the cars. If it is desired to handle very heavy trains, manufacturers of electrical apparatus are prepared to furnish locomotives with as many axles provided with motors as needed or, what is a better arrangement, to furnish locomotives made up of multiple units, all units controlled simultaneously from the cab of one locomotive by one control in the hands of one operator. A train can be either double-headed, or these units distributed throughout the train. One peculiar availability in electrical handling of heavy trains comes from doing away with the limitations of capacity due to man-power or steaming-power of the boiler. Steam locomotives of very high power can usually hold their rate for only a short time, because they are unable, either through lack of boiler capacity or lack of ability of the fireman to stand the pace, to supply the maximum requirement of steam. It was a matter of personal observation with us that, in the case of the large mountain locomotives used on the Santa Fe, on the mountain runs between Trinidad, Colorado, and Raton, New Mexico, and between Raton and Las Vegas, the fireman was unable to keep up the rate of steaming as coal was used toward the back of the tender, and it was customary whenever possible, to pick up a tramp and carry him on the locomotive to throw the coal down to the fireman, in order to get around this.

In an electric locomotive, provided the working conductor is suitably designed, the locomotive will maintain its output to the end of the run, this taking for granted, of course, that in the case of a direct current locomotive, the locomotive is chosen of proper power so that the disturbing element of heated resistance-grids will not interfere. In some cases this ability to handle heavy loads has been the cause of electrification. Thus, at the Sarnia Tunnel on the Grand Trunk, considerable difficulty was had in handling freight through the tunnel with steam locomotives. Under steam operation, freight trains had to be cut in two in order to pull them through the tunnel. The tunnel has been electrified and the trains are now sent through in their entirety, the capacity of the tunnel being estimated to be increased from 12,000 1000-ton trains per year, to 35,000 1000-ton trains per year.

6. The flexibility of multiple-unit operation makes electrification extremely desirable in handling suburban traffic. The coal consumption of a suburban locomotive will not greatly vary when hauling a four-car train from that when hauling a two-car train, whereas, with electrical operation, the power consumption of a two car-train is but little more than one-half of that of a four-car train. It thus becomes possible to fit the train length absolutely to the demands. If, when a two-car train is needed, two cars can be run, or if ten or twelve cars are needed in a train, ten or twelve cars can be coupled together, using due proportions of motor cars, and run as a train, it will be possible during the middle of the day when demands are light, — instead of running a six-car train at half-hour intervals, say, to run three two-car trains at ten-minute intervals with very nearly the same expense. This will be a good deal of accommodation to the public and will meet its return in increased travel. If the interval between trains is too far extended, people will take to the surface lines rather than wait for trains, while a more frequent service would insure continual patronage of the suburban line. Similarly, the congestion during rush hours can be taken care of by doubling the number of coaches and utilizing the same crew. Experience has proved that with electric operation, it is possible to run more cars to a train than under steam operation, and that it is also necessary to run more cars to a train in order to take care of the crowd attracted. Thus, on the Manhattan Elevated, 5.3 cars to a train are run against 3.8 under steam operation. On the South Side Elevated six or seven-car trains are run against four-car trains under steam operation. On the Long Island Railway the standard train to Rockaway Beach was a six-car train under steam operation, while present observation leads us to the conclusion that a ten-car train is nearer the standard now. At any rate, ten-car trains are frequently run.

7. The more rapid acceleration available from electrical working permits of reduced running time with consequent greater mileage. At present steam locomotives accelerate at a rate, for freights, of from one-tenth to three-tenths mile per hour per second; passenger trains from two-tenths to five-tenths, and occasionally as high as seven-tenths. Electric locomotives accelerate at about six-tenths mile per hour per

second, while multiple-unit trains usually accelerate at rates between one and two miles per hour per second, it being practicable to accelerate under electrical working at rates of $2\frac{1}{2}$ to 3 miles per hour per second, but hardly desirable.

Take the case of a steam road operating a train scheduled to 30 miles per hour between stops, and with one stop every two miles. An acceleration of $1\frac{4}{10}$ miles per hour per second would give a ratio of maximum to mean load at the axles of over 10 to 1, and would entail very poor economy. This acceleration, however, is nothing extraordinary in electrical working and is easily attained under practicable conditions. The Metropolitan Elevated uses an acceleration of 1.64 miles per hour per second, according to Dawson; while the Subway accelerations vary between $1\frac{2}{10}$ to 2, depending upon the character and weight of train. This increased available acceleration has brought, in almost every instance, an increase in speed at which the trains are run. Thus, in the various elevated systems, schedule speeds have been raised under electrical operation from those under steam, as follows:

	Steam	Electric
Lake Street Elevated....................	12.5	15
Manhattan Elevated.....................	10.1	15
Brooklyn Rapid Transit..................	11.5	15.8
South Side Elevated.....................	13.08	14.95

Heft gives the following figures for the operation of the Nantasket Beach electrified line of the New York, New Haven & Hartford railroad:

North Bound Branch of the N. Y., N. H. & H. R. R.

	Length of Line	No. of Stations	Schedule Time	Average Speed
Steam, 1894	6.95 miles	10	25 to 35 min.	16.7 to 11.9 m. p. h.
Electric, 1897	6.95 "	16	21 "	19.8 m. p. h.

The headway on the Manhattan Elevated was reduced from 70 seconds to 33 seconds because of the better acceleration and more perfect control afforded by electrical working. The Long Island Railway on putting on its electrical service, cut five minutes from the running time from Rockaway Park to Brooklyn. The North Eastern in its Newcastle electrification, cut the running time 25% upon the inauguration of its electrical service. The Lancashire and Yorkshire on its suburban runs out of Liverpool cut the running time from 54 minutes down to 37 minutes in one instance, and from 25 minutes to 17 minutes in another.

8. Switching under electrical working would be considerably reduced. In the case of suburban trains coming into a terminal, instead of the locomotive having to switch out from behind a train and up to the head of it to get out, the employment of multiple unit trains requires no movement, the motorman merely taking the control handle to the other end of the train. In the case of the operation of through passenger trains into terminals, the customary passage of the train to or from the storage yards, attached to a switching engine, and the proceeding of the regular engine to the station from another point, can probably be done away with by having the passenger locomotive make up its own train. If the routine should not be this, the adoption of a routine such as is in force in the New York Central terminal is allowable, whereby the electric locomotive from an incoming train takes its position at the head of an outgoing train immediately after the train it comes in on comes to rest, and is then immediately available for outgoing service, instead of having to go to the round-house and back and consume a couple of hours, as was the case when that terminal was operated by steam.

In the case of freight switching a good deal of saving in switching movement may be expected because of the ability to put the electrical locomotive exactly where it is wanted. In spotting it is very often the case that the right position of the car means an awkward position for stopping the locomotive, and consequently the car runs a little past its desired position and two or three attempts have to be made before the car is finally located exactly where it is wanted. The electric locomotive will start or stop at any position and the car can be spotted at the first attempt. With a switching locomotive designed with four or more motors under full-series parallel control so as to allow of the minimization of rheostatic losses, or with voltage control in alternating current locomotives, we shall have a locomotive which is equally efficient at a number of variations of load. This will allow of a chance to handle light freights as economically as abnormally heavy freight trains and will probably lead to an ability, in case of badly congested terminals, to haul small trains of cars from the terminals as fast as they are loaded out to clearance yards, or will enable a small fast freight service to be afforded, which is greatly desired by merchants at present, but impractical to operate.

9. With electric locomotive trucks similar to steam locomotive trucks and with a lessened pound and vibration, it is reasonable to expect that the track will be somewhat easier to maintain. On the Burgdorf and Thun road, the maintenance is stated to be less than

that of similar steam roads. (Tissot, Note sur la Traction Electrique des Chemins de Fer.) The supply of abundant auxiliary power should work a convenience and allow various labor-saving appliances to be installed at freight-houses, machine-shops and other points along the road.

10. The possible better condition of road-bed and a lessened wear and tear on rolling-stock should reduce the derangements of traffic if electrical operation be adopted. Certainly, in the case of multiple-unit suburban trains, the breakdown of the entire train would be improbable, as such trains usually contain several motor cars, and the going wrong of one motor car would merely incapacitate that car and allow it to be towed in by the others, while a breakdown under steam haul of such a train would delay it until help could be sent. We have already seen where the delays of trains going into the New York Central Grand Central Station had been cut in half, even before the entire terminal was put under electrical operation. Messrs. Stillwell & Putnam ("On the Substitution of Electric Motors for Steam Locomotives,") give a record of delays on the Manhattan Elevated from November, 1900, to March 1901, under steam operation, and for the corresponding months in 1905-6, under electrical operation. The car-mileage per minute delay was 2,243 under steam operation and 4,268 under electrical operation. These are very significant figures, because they represent traffic during winter months, when the interference of snow and sleet with third-rail operation is at its maximum. Later figures of the operation of the Interborough Rapid Transit Company, covering records during 1907, give an average time-loss per month on the Manhattan Elevated of 339.7 minutes with the average car miles per minute delay of 16,471.

While the economies to be effected by electrical working in a terminal system where traffic is dense present a very attractive side, it is probable that electrification to the railroad becomes most desirable from another side,— that is, because of the capacity to do a larger business under electrification over a given trackage. Ability to do a larger business over terminal trackage in places like Chicago, we believe, will be admitted as extremely desirable on all sides. The capacity of a railroad is the capacity of its terminals, and the trend in Chicago is to increasingly tax these terminals so that in the past few years we have seen additional trackage put down and additional yards provided together with one new terminal station under way and another planned. Increased demand upon terminals may be met in two ways; either by increasing the existing plant or by so equipping it as to allow of a larger output with a smaller investment for equipment than for added terminal space:— namely, to electrify it. This would seem the logical thing to do. The railroads do a business with a large burden of fixed charges. They do business upon a very close margin — how close, we have just seen in a panic the effects of which have not yet passed. It seems almost an unsafe business to the man who is accustomed to working on a comfortable margin. The dependable business just balances fixed charges, as a usual thing; it is from the fluctuations above the dependable business that the earnings must come. If a fluctuation beyond normal, which comes in prosperous years (which is also accompanied by a permanent increase) be large, the railroad must increase its investment to take care of it. Consequently the annual permanent growth of business and the annual permanent increase of fixed charge keep pace, a definite percentage ratio persisting. Now if we can take care of the annual increase for some time by electrification, at a smaller proportionate increase than would be the case by installing additional trackage, we will cause the operating expenses to become a larger proportion of the total and the fixed charges a smaller one. Hence, when business gets bad and traffic movements decrease, a larger proportion of the charges against earnings will automatically be extinguished than at present and the result of the curtailment less severely felt, since operating expenses are almost directly proportional to train movement.

The increased flexibility resultant is also a most valuable characteristic in electric traction — indeed so valuable may it be as to outweigh all questions of economy. Two great desiderata may be obtained with it — the handling of suburban traffic to tbe best advantage and the clearing out of freight yards as fast as freight accumulates, rendering possible a more concentrated working of freight terminals and rendering possible, perhaps, the establishment of profitable express freight service.

Suburban traffic may become particularly valuable. It is regular and it is dependable. It is doubtful if it will be appreciably affected during hard times; and (if it can be profitably developed) it will be a great help in tiding over bad periods such as the railroads have just passed through. Because of its regularity, properly developed, it enables a maximum traffic to be taken care of with a relatively small organization. Where it becomes of large volume the effect of circus and race-track and similar crowds will not serve to disorganize its working as at present, as such crowds will then demand a relatively small increase in facilities. Developed to its proper degree, it represents bulk transportation, and its development as such is the key to its proving remunerative. It is analogous to a manufacturing business which becomes successful because it confines its manufacturing to a few standard articles, making them in large quantities with little outlay for clerical force or development. Now such traffic is to be especially desired for two reasons: It is a traffic whose increase in receipts is faster than the increase in expenses; it is a fixed quantity not affected by hard times. Properly safeguarded, it may be expected to increase always and not diminish. This, we believe, is the attractiveness of electrification to the English railways. In England facilities for suburban traffic by street cars or interurban lines were not afforded as early as in this country, partly because of inertia of promoters, and partly because the traffic was already in the hands of the steam railroads. The steam railroads have awakened to the fact that unless they afford the public better facilities than at present, this traffic may be taken away from them by other agents, and so, to forestall the growth of suburban and interurban electric roads, they have chosen to electrify their systems, — announcing that their purpose therein is not so much to save money as to make money — that is, by doing a larger business.

It appearing that electrification possesses undoubted advantages both for the railroad and the public, let us examine where the disadvantages may lie.

These are usually advanced as being of two kinds — those lying with certain conditions which may tend to the derangement or interruption of services on certain occasions, and those which offer dangers to life and to property. These we believe to have been greatly magnified by opponents of electrical traction, and many to be advanced without good ground.

One of the first objections raised to electrical working is that the concentration of power at one point makes it more vulnerable to injury and makes it possible for an injury to one point of the system to tie up the entire working. While the concentration of power at one point makes it possible to interrupt the entire system by local injury such as a fire, it also largely reduces the number of places at which injury may occur, and the single plant involved permits the employment of safeguards which it would be prohibitively expensive to employ at a number of points. That a fire could occur in the power-house and destroy its working is entirely possible, but highly improbable. Large power-houses such as would be used for railroad power-stations can be constructed almost absolutely fireproof, and, while there are thousands of power-plants scattered through the United States, it is very seldom that one is burned and the power-plants that do burn about the country are the small ones and not the ones of large fireproof construction. The street-railway power-house in Baltimore was about the only building for blocks which was not ruined by the fire and the power-house was put into service very shortly after the fire. The experience of numerous power-houses for electrified railroads and for heavy electric traction systems in this country and abroad, does not afford a single instance of such interruption of service. Some risk must be taken as a usual thing in every betterment in working. To refrain from electrifying roads in Chicago, through the remote possibility of interruption because of a fire in the power-house, would be about on a par with refraining from entering the city at all because a bridge over one of of the rivers in or near the city would constitute a weak point in such entrance, and this bridge might be run into by a passing boat and the traffic interrupted. It is unlikely, should there be a general electrification of the railroad terminals of Chicago, that a railroad would establish its systems without emergency connections to the power-supply at the other terminals, so that in case of derangement, power could be drawn from them. There is also open the arrangement that they have in the New York Central electrification, of duplicate power-houses at different points in the system, each one capable in times of emergency of carrying sufficient overload to tide the system over.

The objection is brought that cables or other conductors carrying the current may become grounded and burn out, thereby cutting off the power. This, of course, is likely to happen with any electrical system. It has happened on certain circuits of the Commonwealth Edison Company; and a manhole explosion once cut off one of the large New York power-houses for several hours. Such troubles, however, are usually unusual and are largely obviated by installing the more important conducting systems in duplicate. Nobody in Chicago would think of lighting a store with kerosene lamps for fear that his electric power might be shut off because of a grounded main belonging to the public-service corporation, and it hardly seems reasonable for the railroads to defer taking advantages of the opportunities afforded by electrical traction, because of so small an obstacle as this,— especially when in such a case the through trains could come in temporarily under their steam locomotives and the people who make use of the suburban traffic could probably find other means of reaching home for the time being. We do not believe that it would prove any very great factor in disarranging suburban traffic, because it has not done so in the case of numerous elevated, subway, and surface-car electric systems throughout the world.

It has been claimed that electric motors are more susceptible to derangement than steam locomotives. Their absence of complication and cleanlier working make this seem improbable and the records of costs of repair and upkeep certainly do not bear this out. Small defects can be better taken care of on the road, with electric motors, than with steam locomotives. A motor has a greater capability of limping along under derangement to the end of its run than a locomotive, and in the case of multiple-unit trains, the motors on a motor car may be entirely out of service, but the other motor cars on the train will serve to carry the train into the terminal. We should expect, therefore, fewer interruptions to traffic than under steam operation and the experience of electrifications of steam and elevated railroads already quoted, bear this out.

Mr. Wilgus, in his paper on the New York Central electrification, before the American Society of Civil Engineers, gave the delays of the New York Central into its New York terminal as 1.2 minutes per thousand train miles under electric working, against 2 minutes under steam working.

Through the courtesy of Mr. W. S. Murray, Electrical engineer of the New York, New Haven & Hartford railway, we were enabled to see the record of train delays on the New Haven for approximately the week preceding our visit. The sheets were practically clean. There was one minor delay properly chargeable to electrical working, and this was a man failure and not a failure of electrical apparatus. Before the New Haven had thoroughly inaugurated its electrical system and had overcome the natural hindrances to operation which come of the inauguration of any new system (and which come particularly when two systems are being operated jointly, as was the case when partly under steam and partly under electrical operation) it was criticized by foes of electrical traction (and of the particular system of electrification employed by the New Haven) for certain delays, which however, upon investigation have proved largely to have been always due to certain troubles (now past) in the power-house, and not out on the road itself. Occasionally certain combinations of circumstances make trouble in a new power-house for the time being; therefore, this trouble on the New Haven is ascribable more to a combination of unfavorable circumstances than to an unfavorable system. The New Haven has been the most criticized electrification in the country on account of delays, and there has been a disposition of the opponents of electrification to rest their case on the New Haven's record. As the New Haven's troubles are now overcome and in view of the very satisfactory operation which the writer observed for himself, he is inclined to believe that the objection is without ground.

Objection is raised to electrical working because of possible interruption of service through electrical storms affecting conductors. It is customary now to thoroughly protect these systems by lightning arresters, and cases of interruption from these causes have become comparatively rare. With a duplicate transmission line, there seems little possible danger of interruption from this source.

The record of the Long Island Railway is illuminative on these points. For the care of their high-tension line they have two crews consisting of only four men,— this to cover the care of an electrification which comprises over 100 miles of electric trackage. The crew consists of a foreman, two linemen and the chauffeur of a gasoline car to transport them from place to place. In 1906, on their high-tension line, there were only 69 insulators broken from various causes out of 69,000. During this year they had several short circuits due to metallic substances being thrown across wires, but no serious trouble. It was necessary to replace 250 third-rail insulators a month out of 50,000. Their rail-jumper repair gang comprised only two men. In this year the chief repairs to third rail, aside from replacing third-rail insulators, were the replacing of some rail protection boards damaged through accident, which two men were able to take care of.

On the West Jersey and Seashore railway in July, 1907, two high-potential insulators were broken, out of 32,000 on the line, and none were broken in May and June of that year,— a breakage in three months of 6-100 of 1%. In July, 1907, they had 91 broken third-rail insulators out of 82,000, or 1-10 of 1% breakage. Their trouble record for July, 1907, showed for 125 miles of track, 3 broken third-rail protection posts, 11 defective protection boards, 1 defective jumper. In June, 1907, it was necessary to replace 34 contact shoes on a car mileage of 292,767. There were 59 car defects in this month and 9 detentions with a total of 90 minutes from defects or 32,529 car miles per minute detention.

There has been some criticism of electrification because of fancied danger to the public and to employees of the road. A careful investigation will show that the bulk of the accidents on electrified railroads due to coming in contact with electrical apparatus, happened to trespassers. There does not seem to be very much danger to passengers or to employees, provided proper and reasonable care is exercised.

Mr. Wilgus states: "During the period of a year and a half that the working conductors have been energized in the congested initial electric zone of the New York Central, not a fatality has occurred there to employees or the public primarily due to third-rail or transmission lines. Three instances have been due to trespassing on the transmission line, another to a porter reaching beneath the rail for a pack of cards, and one to a prior contributing cause." (Proc. Am. Soc. C. E.)

On the Valtellina line, in the first four years of operation, no one was injured on the line by the electrical apparatus. During this time the only fatality which occurred throughout the system was the killing of one of the engineers employed by the contractors installing the system, through getting into some of the apparatus at one of the substations.

On the Lancashire and Yorkshire railroad in England, when first opened, a number of people were killed through contact with the third rail, but after the system was put in working order, for considerably over a year there was nothing in the nature of a serious electrical shock or accident.

The Board of Trade returns covering the electrifications in Great Britain for 1904-5-6 and to August, 1907, showed 16 killed and 71 injured throughout Great Britain. Of the people who were killed in the four-year period, 4 were railroad servants and 12 trespassers. Of those injured 40 were railroad men, 1 was a passenger, 5 were people on business with the railroad, 25 were trespassers. Of these casualties, the North Eastern had 8 killed and 28 injured, and the Lancashire and Yorkshire had 5 killed and 19 injured. The 16 killed during the four-year period represent the casualties not only on the electrified railway systems in England, but on the various third-rail systems employed on elevated, subway, and similar systems throughout Great Britain.

The Connecticut legislature, shortly before the completion of the New Haven electrification, passed a law requiring that no part of a railroad equipped to be operated by electricity be opened for public travel, unless the company operating same should first obtain a certificate from the Board of Railway Commissioners that such railroad, or part thereof, was in a "suitable and safe condition." Regarding the New Haven electrification, the current report of the Commission states: "After a thorough examination of the system by the full

Board, assisted by an electrical expert, we certified that the same was in a suitable and safe condition, as required by the statute."

The report of Mr. William R. C. Corson to the Connecticut Railway Commission, which report was presented by them as a part of their annual report, states regarding this system: "Doubtless experience coming from actual operation will disclose weak features and defective apparatus and possibly unthought-of hazards may develop, but, as a whole, I am unable to conceive of any condition of danger to the travelling public which can arise from the electrical features of the system adopted."

Criticism has been made of electrical working, because of the accident to the New York Central, February 16, 1907, at Woodlawn, when the White Plains & Brewster Express, consisting of five cars and two electric locomotives, was derailed and 20 passengers killed and 150 injured; and because of the recent wreck of the White Mountain Express on the New Haven. Why a case of too high speed on a curve or of spread rails should be laid particularly at the door of electric traction, seems hard to understand, especially in view of the fact that six days after the New York Central accident, the celebrated wreck of the Pennsylvania "Flyer" occurred, through apparently similar causes and with equally fatal results; and wreck after wreck occurred through track defects about the same time. It is very probable that had a steam train taken the curve on the New York Central at the same spot as the electric train and at the same speed, the same accident would have occurred; and in the New Haven case, it was apparently a case of spread rails, which may have been due to the design of the locomotive — but if such was the case, the fault lay not with an electric locomotive, but with a locomotive without pilot trucks — that is, the fault was mechanical and not electrical. The experience of the New Haven, we are told, has been that the effect of the operation of their locomotives has been to reduce the number of broken rail joints, (which is reasonably to be expected because of lessened vibration) but not to decrease the number of spread rails, which we should also expect because of probable "nosing" through lack of pilot trucks on the locomotives. Abnormally high speed may have been a factor in the New Haven accident. At the time of our visit to this system, several motormen were being disciplined because of taking curves at too high a speed.

The prediction is sometimes made that in the case of a wreck of an electrical train, the wreck will be burned or the passengers electrocuted. Undoubtedly, cases have occurred where collision of electric cars has caused a fire which has destroyed the cars. Thus, a fire in the New York subway on June 1, 1906, through a collision, burned three unoccupied cars. At the same time there have been numerous other collisions of electrical trains in which no such action has occurred. Thus, at just about the same time, on the Long Island Railway, a train of steel motor cars going at high speed, demolished three freight cars without damage to themselves. Apparently the case is about the same as with steam railroads. There are numerous steam-railroad wrecks in which the cars are not burned and there are others in which the cars and the passengers within them have been burned,— such as the Southern Pacific wreck several years ago, between Benson and Tucson, Arizona. There are accidents such as the accident in the Paris subway shortly after its opening, where an electrical train caught fire and a number of passengers were smothered to death in the subway, trying to escape. But there are similar steam accidents, such as the accident in the Park Avenue Tunnel on the New York Central, and the accident on the Grand Trunk in its St. Clair Tunnel, in the fall of 1904, before its electrification, when six of the train crew were suffocated because of the train breaking in two while passing through the tunnel and leaving them amidst gases from which they could not escape.

When all is said, it is probable that the after-effects of a wreck are equally hazardous under steam or electrical working.

Objection has been brought to electrification because of its interference in wrecking operations, preventing the throwing of wreckage to one side of the track in clearing the track, in cases of third-rail installation and preventing the use of locomotive cranes in the case of overhead construction. While there could be some objection from this score, tracks around Chicago are usually in duplicate and permit of wreckage being permanently removed instead of piled off to one side,— trains passing around the wreck in the mean time.

Objection has been brought to electrification because of possible electrolitic action on surrounding water-pipes etc., and its interference with neighboring telegraph and telephone wires. While this danger would perhaps exist with an electrified steam road, it exists in greater measure with the electric street-car systems, and when it is not a deterrent to electrical working there, it should not be with electrical working of standard railroads. With their numerous parallel tracks and large track-return thus afforded for the current, with the rock-ballast underneath the track forming a very fair insulation, with the tracks confined mainly to rights of way which do not carry water pipes or public-service wires, and with their elevation above crossing streets which carry wires or piping liable to be damaged,— it is doubtful if any acute danger of electrolitic action exists and what action there may be can certainly be overcome by reasonable precautions. Thus in the case of telephone and telegraph wires on existing electrifications where these wires are carried close to the conductors, there have been adopted means of protection for them which are reported to be amply sufficient. On an existing single-phase installation such troubles were entirely done away with in adjacent telephone wires by rotating the wires to get rid of the electro-magnetic induction and earthing a connection at their middle point with a choke coil inserted, which would not permit the telephone current to pass.

It has been urged against electrification of terminals that it will produce a great many complications and conflicts in the case of party tracks and joint use of terminal facilities. That existing arrangements would have to be modified under electrification, nobody doubts, but these arrangements have to be modified every time any permanent improvement is made by the railroad, and if existing arrangements permit of modifications for improvements, such as track elevation, different round-house facilities, storage yards, etc., it is hardly reasonable to suppose that the necessary modifications of existing contracts or agreements could not be made for the proper changes and proportioning of expenses under electrical working.

It has been advanced that to electrify the Chicago terminals would produce more or less disorganization of the divisions having their terminals in Chicago. This would seem to be the most valid objection to the electrification. The railroads arrange their divisions, as a usual rule, so that certain mileage runs will be made by their employes from one end of the division to the other and arrange division plants for taking care of locomotives and rolling-stock at the end of their runs. But the ideal division arrangement apparently is to have divisions of about 100 miles in length each, so that 100-miles mileage can be given the train crew on the train between division points. However, this is not practically possible, and the length of division varies. If divisions were absolutely fixed, their positive unbalancing by taking 15 or 20 miles from the Chicago end of them might be a serious matter; but they are continually changing and every time a new connection or branch is opened up, it submits the division to similar unbalancing to what would occur by electrifying the Chicago terminal,—so that while this unbalancing might create some confusion at the time, it would be nothing new and, having been taken care of in the past, should be able to be taken care of in the future.

The objection is urged that the work incident to electrification might lead to a derangement of traffic during the electrification. This is hardly tenable in the case of third-rail construction, as it would not be necessary to change the road-bed construction, but simply to remove about every fifth tie in a similar manner to the removal of ties from day to day to replace decayed ones, and to substitute a tie long enough to carry the third-rail support at its extremity. The track spacing in Chicago in general, owing to the overhang of car bodies, is sufficient to permit the installation of such a rail. In the case of overhead construction, the traffic need not be deranged as the columns for the bridge carrying the overhead work can be set at the side of the track without interfering with traffic and a transverse girder very quickly dropped into place by a wrecking train, as was done in the erection of the New Haven bridges. Stringing of the trolley wire is comparatively rapid and need not get in the way of traffic.

The railroads around Chicago in general, are elevated so that they would not have to contend with the difficult problems of grade crossings or of the prevention of trespass. With most of the Chicago roads except for certain tracks at street level, it is simply a question of fitting the electrical apparatus to the road and there is none of the physical preparation of the right of way which has been necessary in so many of the electrifications in other cities. We do not believe that the traffic would be materially deranged by electrification,— but if it should be it would appear that the present is precisely the time to undertake the work before it has to be done under worse conditions in the future. Times are dull now, material is cheap, labor is plentiful, traffic is less than it will be later on. It seems the ideal time to undertake the work.

If the work of electrification is undertaken it would seem that a complete electrification should be undertaken rather than a partial one, else the greater economies cannot be expected. A large part of the economy of electrification comes from increased cleanliness and a reduction of dead time and similar wastes. If steam and electrical traction are undertaken side by side, the disadvantages of one will largely nullify the advantages of the other and the wastes will be multiplied by two. President McHenry of the New Haven says:

"The simultaneous maintenance of the facilities and working forces for both steam and electric service within the same limits will be rarely profitable, for the reason that a large proportion of expenses incident to both kinds of service is retained, without realizing the full economy of either. To secure the fullest economy it is necessary to extend a new service over the whole length of the existing engine stage or district, and to include both passenger and freight trains."

SYSTEMS AVAILABLE FOR ELECTRIFICATION

H. H. EVANS

We come now to an examination of the general features of the various systems which are available for the electrical working of steam roads. This examination is of interest principally in enabling us to ascertain whether the various mechanical problems which would be presented by electrification in Chicago, have been met with in existent electrifications, and means adopted to successfully solve them. Some examination into the history of electrification systems will be of value, in that it will enable us to ascertain whether these systems are of long enough standing to have passed from the experimental to the practical state. Some examination of the details of the existing systems is also advisable, to ascertain whether these systems contain features which might be objectionable from the public point of view,— in that they might endanger life or property or make the uninterrupted working of such a system uncertain.

The problem of the electrification of standard railways is not a new one, but its solution was aimed at in the earlier stages of electrical development. Long before electrical working was applied to street-railway operation, or even before street railways were in general use, experiments were made looking toward electrical working of standard railways. Experiments were made in 1834 by Davenport, and shortly afterward, Davidson made an experiment upon a Scotch railway. C. G. Page, in 1850, received a grant from the United States Congress of $30,000 with which to undertake some experiments. He constructed an electric locomotive driven by Bunsen batteries and succeeded in making a speed of about 18 miles an hour without anything practical coming of his experiments. Shortly after this, Pacinnotti advanced the idea of using a fixed power-house and aerial conductors, but apparently nothing was done toward carrying this into practice. Various miniature roads and electric locomotives were exhibited at expositions and similar places for a number of years, but to the public at large they were little more than "side shows." However, each marked a development in invention and a nearer approach toward types which are found practicable to-day.

Siemens and Halske, Edison, Field, and Daft were all concerned in work of this kind. In 1884-85, Daft made a study of the electrification of the Manhattan Elevated, this road seeking some means of getting greater movement over their road than they were able to obtain with steam. During these studies a three-mile section of this line was equipped with third rail and an electric locomotive used in hauling trains. In 1886 Sprague made a study of the same problem and in 1887 made some tests on the Third Avenue Elevated, installing a third rail, 600 volt, direct-current system with motors mounted upon trucks of a single coach. In the equipment used in these experiments much of the present street-car electric equipment had its birth.

About this time the possibilities of electrical working of street-railway lines became apparent and most of the very able inventors turned their attention to street railways and work upon heavier roads went more or less into the background. Sprague, Vanderpoel, Daft and others attacked the problem of street-railway equipment vigorously and with the successful working of the street-railway system in Richmond, installed by Mr. Sprague, the present wonderful development of street-railway lines grew by leaps and bounds.

In 1889 the Manhattan Elevated railway made further electrification experiments. Unfortunately, electric locomotives were contemplated which were not so well adapted for this kind of work as the motor-car system, so successfully adopted later,— and, because of the showing made, the Manhattan Elevated abandoned the idea of electrification for the time being.

The City and South London subway inaugurated in London, December 18, 1890, a system three miles long, run by electric locomotives, and hauled trains of 30 to 40 tons weight. This was a primitive installation, but well installed, and gave results which were considered satisfactory both from a financial and an operating standpoint. The equipment continued in service until 1898, when it was modernized and multiple unit trains substituted for those hauled by locomotives.

In 1893, the Intramural Road at the World's Fair made use of a sliding-shoe contact to gather the current from the third rail and demonstrated the applicability of this system of collection which allows of almost unlimited quantities of current being picked up while under way. The operation of the road was very successful and it served as a type for the electrification of the various Chicago elevated roads. The Metropolitan Elevated road ordered steam equipment, but the successful working of this South Side railroad caused them to cancel their order for steam equipment and provide for the electrical working of the road.

In the meantime, the South Side Elevated had undertaken to electrify their line, and for them the multiple-unit system was devised, and with the successful operation of this system on this railroad, in 1897, third-rail, direct-current operation may be said to have been perfected, — subsequent improvements merely being in the nature of detail improvements. Following the adoption of this system, the remaining elevated railroads in the United States were rapidly electrified, and the third-rail interurban railways began to be constructed between various points, as well as this system adopted for various electrifications of standard steam railways.

The first real application of electrification to a standard road was in 1895, however, when the Nantasket Beach line of the New York, New Haven & Hartford Railroad was electrified, and electrical working was applied to the Baltimore & Ohio Tunnel in Baltimore. Electrification experiments were made on standard European roads before this time, and, beginning with 1893, a good deal of activity was manifested by them. Their experiments, however, took the direction of propulsion by storage-battery locomotives and cars, and systems with similar apparatus designed to supply a self-contained motor vehicle.

As the most general system in use at present has been in existence in its entirety over 11 years, and in all of its major features, with one exception, for 15 years, it can hardly be termed experimental.

The systems employed in various electrifications in general are operated with a direct current of 600 to 650 volts, supplied usually by a third rail; the single-phase system, with voltages from 500 to 15,000, supplied by an overhead conductor; and the three-phase system with the current supplied usually at high voltages through two overhead conductors. The high-tension, direct-current system is also coming into use and gives great promise.

Standard Direct Current Construction.— The most generally used system employed in the electrification of heavy railways is that of the direct-current third-rail system. Power is generated in a powerhouse by generators which are direct-connected to steam engines, steam turbines, or gas engines, as may be best suited to the service. If the line be short, direct current may be generated and fed into the working conductors, but owing to length of line necessary to be electrified, this is very seldom the case. The Baltimore & Ohio Tunnel at Baltimore is one of the few examples of this. In general, the current is generated as a three-phase alternating current and transformed for use on the line. It may be generated at the voltage used in the transmission lines or at a lower voltage and the voltage stepped up before transmission in static transformers, a high voltage in the transmission line being desirable in order to prevent dissipation of current in transmission and in order to permit of the use of smaller wires for transmission. The power-station may contain one or more units which generate direct current for the working of the section immediately adjacent to the power-house and the rest of the units alternating-current ones, but generally the whole of the current is generated as alternating current, a sub-station containing the necessary transforming apparatus being embodied in the equipment of the main station to supply that particular portion of track. It is customary to provide the power-house with water-tube boilers on account of their quick steaming and allowable use of high pressures; and various refinements such as feed-water heaters, super-heaters, etc., are supplied to these boilers in order to afford the utmost economy.

The coal is usually discharged from the cars in which it is delivered, into a hopper underneath the car, whence it passes through a crusher, and by a mechanical conveyor to a bunker in the upper portion of the boiler-room, whence it feeds by gravity through suitable discharge spouts to mechanical stoking apparatus, by which it is carried underneath the boiler and fed in at the most economical rate. The ashes drop underneath the boiler into a bin, whence they are tapped onto a conveyor and carried to a hopper above the unloading place for the coal cars. When a sufficient amount of ashes collects and a car has been emptied of its coal, the ashes are run into the car and carried off.

The current goes from the generators through oil-switches to the bus bars of the main switchboard, whence the current is taken off to the separate circuits through oil-switches and carried to the various sub-stations, where, by means of rotary converters or motor generator sets, the alternating current is converted into direct current of the required voltage. Before passing into the converting apparatus at the sub-station, the voltage of the current is first stepped down by means of transforming coils to a suitable operating voltage for the alternating current side of the converting apparatus. Various safety devices are inserted in the circuits, such as overload and reverse-current relays, etc. The transmission line from the power-house to sub-stations may be either laid in conduits, in which case paper-insulated, lead-sheathed, three-conductor cables are usually installed in vitrified tiling ducts enclosed in cement with manholes at intervals; or carried by bare, overhead wires, in which case the wires are carried on insulators on the cross-arms of the transmission poles or towers. Where it is necessary to cross rivers, a three-conductor rubber and lead-covered armored cable is usually laid in a trench in the bottom of the river, the trench being afterward filled, or allowed to fill up by the sediment in the river bed.

Wherever the transmission wires enter or leave a sub-station and wherever they go from underground to overhead, or vice versa, lightning arresters are customarily installed, special houses being installed, in the absence of sub-stations, to contain them — cut-out switches, also, usually being installed.

The direct current from the converting apparatus at sub-stations is led to the direct current bus-bars, thence through circuit-breakers to the separate circuits which it is necessary to supply with current. In third-rail construction it is usually sufficient to treat the third rail from one sub-station to another as a continuous conductor, simply tying in the ends of the rail to the sub-station buses through suitable cable. Where the third rail is interrupted at crossings and such places, the current is carried past the crossing by jumpers connecting the ends of the interrupted rail. These are customarily paper or cambric insulated, lead-covered cables of from 500,000 to 2,000,000 cir. mil. capacity, have lugs on the end sweated on to the cable with terminals attached to the necessary copper cables each provided with a copper block, at the end, which can be soldered to the rail or pressed into holes in the rail to form a connection. The jumper passes across the vacant space, underneath the surface, in a tile or other conduit, or may be laid in a wooden trough surrounded with pitch, or may be even simply buried under the roadway as in the case of the Long Island. It is customary to cut the rail, between sub-stations, into sections united by jumper cables, which cables pass through a switch-box, the switch in which may be opened to cut the current from a particular section of the third rail to allow of the rail being repaired without danger to track laborers. At important points a similar interruption may be made and the current led through a circuit-breaker contained in a house for the purpose, so that in case of an abnormal rush of current, the current can be shut off and danger or damage to any of the apparatus avoided.

Where there are switches, sidetracks, and similar isolated pieces of trackage, the current is carried from the third rail by jumpers over to third rails laid along the switch or other track; and where there is a complication of track work, a switch-house is sometimes installed to which a feeder cable is led from the nearest power sub-station and the current distributed through suitable switches to the special pieces of track. Where traffic is very dense or where concentration may occur at particular points, it is sometimes customary to parallel the track with feeders which carry direct current from the sub-station and feed it into the third rails through suitable connections, at intervals of 1,000 feet or more apart. Where a third-rail road crosses a highway or goes through a station, where it is impossible or undesirable to carry the third rail across a space, the rail is interrupted and the current carried across the gap by jumpers, as we have already described. This is also the plan carried out in crossing a track. In the case of long turnouts, it is usually possible to secure continuous connection with the third rail by having a third rail laid on either side of the track each side of such point, so that when an electric locomotive passes over such pieces of track the front shoe on one side will begin to take the current from the interrupted rail before the hind shoe on the other side leaves the rail. In cases where there is great complication and it is feared that an electric locomotive might stall on the track in a position where the shoes could not be brought into contact with some portion of the third rail, it is customary to erect an overhead structure to the underside of which, and following the actual lines of the tracks underneath, is attached a number of energized conductors. The electric locomotive carries a sliding collector mounted on what is known as a pantagraph, which affords a vertical movement of the collector and brings the same into contact with the overhead conductor, when air pressure is admitted to the working cylinder at the base of the pantagraph at the will of the motorman. As installed on the New York Central electrification, it was said to be intended that the locomotives should bring the pantagraph shoe in contact with the overhead collectors in order to retain their speed while passing under such structures, but in practice it has been found that the electric locomotives usually hold their speed while passing such places and it is not necessary to take the trouble to bring the overhead collector in contact. They are used now only in case of stalling and, consequently, very infrequently.

Where a third-rail system crosses a river it is usually customary to carry the current from the energized rail on one bridge approach over to the other, through a submarine cable, so that in case the draw is open, the current is not interrupted. It is customary, of course, to carry the third rail over the draw of the bridge, but so arranged, however, as to be cut out of connection whenever the draw is turned.

The current is collected from the third rail usually by means of a shoe which slides upon the rail or is held up against it, depending upon the type of rail used. It passes through the controlling apparatus which is so arranged in general that it will carry the current to the motors at the same time varying the resistance and connecting the motors in series or in parallel, as required. The returning current passes through the axles and wheels into the track rail and back along the track rail to the negative, direct-current, bus-bars. The track rails are connected together by copper bonds so that they form a continuous metalic circuit.

In order to provide for the proper working of electric block signals, the tracks are insulated into sections of the desired length. The signaling system is supplied with alternating current, there being a gap in the circuit, between the two rails, when no train is in the block. When a train enters a block the circuit is completed by the rails being electrically connected through the metal of the trucks and axles of the cars and the signal set at "Danger," by the current working through a relay. In order to allow the return current to return through the track past the insulation of the ends of the blocks, resistance or impedance bonds are connected to the tracks past the insulation. These resistance bonds are made up of a number of thick coils of copper which have a low ohmic resistance, but a high inductive resistance. The direct-current return-track currents pass through them readily, while the alternating-track signals cannot pass. To protect the signal circuit and prevent the entrance of a large volume of direct current returning through the tracks into it, the signal circuit is arranged as a shunt to the track circuit in which an impedance coil is inserted, the bulk of the direct current flowing through the impedance coil and the signal current shunting around it.

The third rail may be of several types. In cases where the track is fully protected from trespass, it may be an unprotected rail laid on insulation blocks of paraffined wood, porcelain, reconstructed granite, or similar material held down by clips turned over the flanges of the rail and imbedded in the insulator and held from creeping by anchor rods. This type will be recognized as the one employed by the elevated systems in Chicago.

Where there is danger of trespassers, passengers, or employees coming into contact with the rail, it may be protected by boards held by brackets attached to the ties or to the rail itself, the boards enclosing the rail except for a slit into which the collector shoe reaches to collect the current.

The under-running third rail has recently come into prominence and is being largely employed. This rail is held by insulators gripped by a C-shaped malleable-iron arm bolted to the cross tie and the rail between the insulators protected by a wood sheathing which encloses the rail except for the bottom contact surface. It is thus necessary for a person to reach up from underneath in order to get into contact with the rail, and it looks as though it should be thoroughly safe to the public. It has the advantage of offering less strain on the insulation, as the shoe acts against instead of with gravity. The board protection, being continuously supported, is less apt to crack and warp, the rail is better protected from the weather and less liable to corrosion, the contact surface is more thoroughly protected from sleet and snow, and the passage of the shoe along the rail tends to clean off sleet and snow instead of packing it down upon the rail into a sheet of ice.

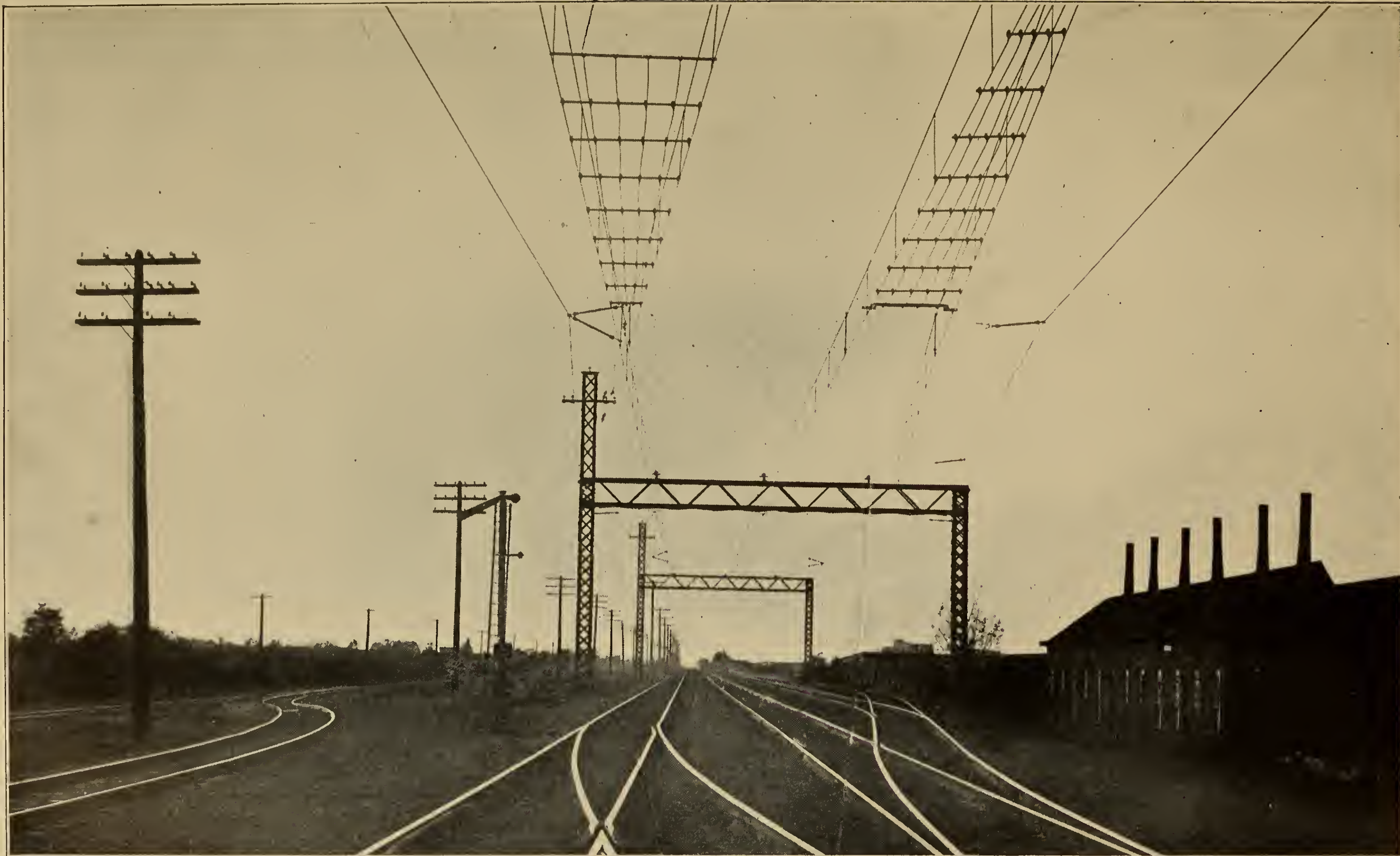
With direct-current working an overhead trolley wire may be employed where the speeds are slow and the quantity of current necessary to be collected is not too high. While such construction would not be satisfactory for heavy electrification, there are tracks where the traffic is light or infrequent where it might be used to possible advantage. This is the construction familiar to everybody which is used in street-railway trolley construction. While the construction as carried out in street-railway practice would have but a limited field, its use might be extended by the adoption of a catenary suspension.

With third-rail systems it is customary to haul through passenger trains and freight trains with electric locomotives, while suburban traffic is usually taken care of with motor cars hauling trailers or a number of motor cars and trailers combined into a train and operated on the multiple-unit system. This system we are familiar with as that employed in the operation of the elevated railroads in Chicago. Third-rail systems have been extensively employed both in heavy-railroad electrification and in the working of numerous interurban, elevated, and underground railroads. Amongst such systems are the:

New York Central.
Paris-Orleans.
West Shore.
West Jersey and Seashore.
Baltimore & Ohio.
Early New Haven electrifications.
Long Island.
North Shore.
Lancashire & Yorkshire.
North Eastern.

Mersey Tunnel.
Milan-Varese-Porto Ceresio.
Paris-Versailles.
Fayet-Chamounix.
Wannseebahn.
Fribourg-Morat.
City & So. London Subway.
City & Waterloo "
Central London "
Great Northern & City Subway.
Metropolitan of London "
Metropolitan District of London Subway.
Underground Electric of " "
Paris Metropolitan Subway.
Buda Pesth Underground Subway
Berlin Underground "
New York "
Great Northern, Piccadilly & Brompton.
Charing Cross, Euston & Hampstead.
Manhattan Elevated.
Brooklyn "
Kings County Elevated.
Boston "
Philadelphia "
Metropolitan "
South Side "
Northwestern "
Chi. & Oak Park "
Liverpool "
Berlin Gross Lichterfelde.
Wilkesbarre & Hazleton.
Lackawanna & Wyoming Valley.
Albany & Hudson.
Aurora, Elgin & Chicago.
Grand Rapids, Grand Haven & Muskegon.
Columbus Buckeye.
Lake & Newark.
Columbus, London & Springfield.
Philadelphia & Western.
Jackson & Battle Creek.
Scioto Valley Traction Company.

The principal objections to the third rail are: that it gets in the way of ordinary track work to a certain extent, that it may interfere with any change in equipment clearances, that its working may be interfered with by accumulations of sleet and snow, that it adds an increased danger in case of derailment, that it is a hindrance to coupling freights, etc., in yards, and that it may be a source of danger to the public.



Courtesy Westinghouse Electric & Mfg. Co.

St. Clair Tunnel Co. (Grand Trunk) — Catenary Line Construction showing Deflectors at Turnouts — Alternating-Current Single-Phase Installation.

As to interference with track work, in case of heavy repairs to the track, traffic will be taken off and the section of third rail along the track be cut off from the current supply. As to interference with changes in equipment clearances, the present lot of tunnels, station platforms, etc., are probably equally interfering.

In regard to derailments, in case of the train forming a short circuit between the third rail and the train itself, the rush of current will be such that the circuit-breakers will automatically cut off the current from the section of track affected.

The experience of the third-rail roads in general and the test made on the New York Central type of protected third rail during heavy snow-storms at Schenectady, lead us to believe that no serious difficulty may be anticipated in maintaining the schedules of third-rail roads on account of snow, so far as it affects the third rail alone. The later types of protected third rail we believe to offer little danger to passengers or people who have to enter the right of way of the railroad.

As a hindrance to the coupling of freight cars, etc., we believe that here there is a good deal of objection to the third rail as it must be a good deal in the way, but the slow speed at which switch-engines run in making up a freight train will allow of sufficient power to work a locomotive being taken from overhead conductors and of the third rail being dispensed with. It will be necessary, too, to use overhead conductors for team tracks and for places where the railroads use the public streets,—such for instance as the tracks on North Water Street or the Illinois Central Suburban tracks from Sixty-seventh Street to South Chicago. The service on the South Chicago branch is similar to the service offered by the Key route in Oakland and Berkeley, where an overhead trolley system is in use.

High-Voltage Direct-Current Systems. — In most direct-current work a limit of satisfactory working is reached with a maximum voltage of about 650. A rise in voltage above this brings a disproportionate increase in problems to the designers and in troubles with operation in ordinary direct-current operation. A rise in voltage is desirable in order to decrease line losses, but the attempt to go beyond 650 volts is liable to lead to trouble, principally from flashing. The larger the motors, the more destructive the flashing becomes. When the current is momentarily cut off a direct-current motor and turned on again; with a large current, flashing occurs if the magnetism has had no opportunity to die down and a large current surges through the windings before the magnetism can rise, thereby causing field distortion. This can be obviated by building motors to secure an instantaneous rise in magnetism. As direct-current motors are built, the solid yoke offers a secondary circuit to retard the field magnetism, and also the armature coils under the brushes form secondary circuits which may have enormous momentary currents set up within them. Freedom from trouble with ordinary working at higher voltages than are at present used may be effected by providing laminated magnetic circuits with no closed secondary paths and no low-resistance secondary paths in the armature winding. The field is provided with neutralizing compensating windings, which neutralize the magnetizing effects of the armature.

This construction, of course, would lead to more expensive motors, and a similar construction of inter-pole generators with compensating coils necessary to generate the higher-voltage current would also be more expensive, but in the case of lines of certain length it will be possible to operate a system without sub-stations over a greater range than is admissible with present limits to voltage; and with the present system retained of a central power-station generating alternating current transformed to direct current at sub-stations, the adoption of a higher-voltage direct-current working would result in smaller conductor losses and fewer, larger, more evenly loaded, and more economical sub-stations both as regards first cost and as regards operating expenses.

The trend at the present time is toward a more extended use of inter-pole motors, even at the present operating voltages, because of their freedom from sparking. While there are only a few direct-current high-voltage lines installed (and a good many of these installed with a make-shift arrangement of running generators and operating motors in pairs in parallel to take care of the high voltage instead of using the full range of voltage in the apparatus), it is evident that this system will take a fairly large place in the near future.

Mr. Frank J. Sprague, in advocating this system, offered to carry to successful conclusion a direct-current installation at a working pressure, even on the third rail, of not less than 1500 volts. Even were there not high-voltage direct-current systems in operation, this offer of Mr. Sprague should make the high-voltage installation seriously considered, coming as it does from a man who did more than anybody else in its infancy to make ordinary direct-current working a success and to whom the world owes the invention of the multiple-unit system of motor car or electric-locomotive working which has resulted in absolute flexibility of electric traction. It is not the wild statement of a visionary, but the dictum of a man who has already won his laurels by eminently practical applications of electricity and who has nothing to gain by being sensational.

In addition to its effects as regards the number and spacing and operation of sub-stations and the reduction of conductor losses, high-voltage direct-current operation offers a great advantage in that it will permit of much higher power being taken off an ordinary trolley wire by an electric locomotive than is possible at the present voltage, and so will permit of heavy freight trains being hauled out of yards to which it may be necessary to apply overhead conductors, rather than third rails, because of obstacles which the third rail presents to teaming and other movements through the yards.

High-voltage direct-current working has had little application in the United States. Probably the first system installed was the Indianapolis & Louisville Traction Company, an interurban trolley system 41 miles long, between Louisville, Kentucky, and Seymour, Indiana, carrying 600 volts on the trolley in the cities and 1200 volts outside. A single-pole bracket construction (No. 0000 trolley wire) is adopted, lightning arresters being installed every 1000 feet. The generators and motors are not built for the high voltage, but the current is generated by two 600-volt generators operated in series, and the motors are operated two in series on 1200 volts, commutating-pole motors being used however

The California Midland system is at present under construction. It connects Marysville, California, with the mines of Nevada and Placer counties, and comprises in all about 70 miles of track and is to operate on 1200 volts direct current using a third rail as a conductor in the country and overhead conductors in towns. The motors for this line will also be 600-volt motors run in series on the high voltage. The Central California Traction Company has a similar line under construction.

Abroad, a number of high-voltage installations have been put in. One of the most notable of these installations in Europe is that of the freight road belonging to the French Government between St. Georges des Commiers and La Mure, in the coal regions in southwestern France. This comprised about 19 miles of single track over a heavy grade, over which a large, difficult traffic had to be handled. It became impossible to handle the traffic by steam and it was found economical (traffic being heavy enough to afford $12,000 per mile revenue) to electrify this part of the line. A 2400-volt direct-current system was installed, a 3-wire distribution being adopted, two wires overhead carrying 1200 volts positive and negative current respectively and the track forming a neutral.

The Berlin Elevated and the Zweisimmen-Montreux use a voltage of 800 to 850. According to *Elektrische-bahnen*, J. J. Reiter & Company is constructing an electric road between Bellinzona and Mesocco, in southern Switzerland, carrying 1500 to 1600 volts direct current, each motor car carrying four 1500-volt motors. The Oerliken Company, in 1906, gave the following list of high-voltage direct current lines equipped by them:

Fribourg-Morat	800 volts
Bremgarten Dietikon	800 "
Chemin de Fer Viveysans	800 "
St. Gallen, Speicher, Trogen	800 "
Wetzikon, Meilon	800 "
Montreux, Oberland Bernois	700 to 1100 volts
Sernftal	800 volts
Schaffhausen, Schleitheim	800 "

The Siemens-Schukert Works gave out the following list:

Cologne Bahn	800 volts
Castellamare di Stabia-Sorrento (Italy, 12 miles long)	825 "
Berlin Elevated and Underground	800 "
Moselhutte Freight Railway (from Maizieres to St. Marie, 9 miles)	2000 " D. C.
Anhalt Coal Works (Reppist near Senftenburg, 4 miles long)	900 " D. C.

Single-Phase Operation.— The arguments which hold good for high-voltage direct-current work hold good in a measure for single-phase working. The construction of motor which it is necessary to adopt for successful high-tension direct-current working is almost an ideal construction for a successful single-phase motor. The single-phase series, commutating motor is really a high-grade direct-current motor. By the use of a motor with nearly standard railway-motor characteristics, most of the advantages of direct-current operation become available and, in addition, almost any potential becomes admissible in the working conductors. By the use of a high voltage the employment of sub-stations and rotary converting apparatus becomes entirely unnecessary and it is possible to construct very long conductor lines entirely without feeders. The employment of such a system with a high voltage requires the collection of small currents, so that no matter what the speed of the electric locomotive or motor car or how small the contact, no difficulty is experienced in collecting whatever amount of power is requisite for the movement of a train. The high-tension current, upon being conducted into the locomotive or motor car is transformed by stationary transformers to a suitable low-operating voltage for the motors; the use of a low voltage on the control system and motors is thus obtained without abnormal transmission losses. The stationary transformers can be so arranged as to afford any desired number of taps so that a voltage control is insured, thus doing away with rheostatic losses. In the typical single-phase system, the power is generated almost exactly as it is in the direct-current power-house. Single-phase generators may be installed to generate the current, or three-phase generators installed and single-phase current taken off of them, the detail of the wiring connections being variable according to the opportunities presented by the lay-out of the line for possible balancing of the phases in the generator. The current is generated directly at 11,000 volts (or whatever desired) and carried into the working conductor for the whole length of the line without feeders, the bonded track forming the return.

In single-phase systems the line construction is usually a catenary construction, either with single or double suspension. Main-line construction demands to be particularly durable. In certain European electrifications, such as a recently completed electrification of the Midland railway on the Heysham, Morecambe, Lancaster division, and on minor American electrifications, such as the Erie, the Annapolis, Washington & Baltimore, and the Baltimore-Annapolis Short Line, the conductor is suspended from a single messenger; while on the very important electrification on the New Haven where expense was secondary to efficiency an elaborate suspension from two messengers was adopted. In general, the line construction is carried on steel bridges about 300 feet apart which span the tracks. These bridges carry insulators on their upper surfaces from which are suspended stranded steel messenger cables which, of course, have a sag between insulators. From the messenger cables at distances of about ten feet hang suspension rods of varying lengths, to the lower ends of which the conductors are attached by means of clips. The sag of the messengers and the length of the suspenders are so chosen that the working conductor hangs always in a position as nearly horizontal as possible and (except for occasionally being offset to equalize the wear on the collector-shoe) over the center of the track. At intervals of about two miles, a bridge much heavier than the ordinary bridge is introduced, which is specially braced to take the longitudinal pull of the messengers and conductors.

The sections of messenger cables usually terminate at them, and they carry section-insulators for the working conductor, although the different lengths of the latter are usually connected in series through circuit-breakers carried on such anchor bridges. The anchor bridges also carry lightning-arresters, shunt-transformers for operating circuit-breakers, etc. The working conductors usually have sufficient capacity for the current, but an auxiliary line may be carried the entire length of the line and connected into the working conductors at the anchor bridges in order to carry the current around a section of conductor which may be out of service. Electric locomotives or motor cars may be operated upon such a system, the high-tension current being transformed inside the locomotive by means of stationary transformers to the working voltage of the motors, transformers being customarily built with multiple-voltage taps, so that a voltage-control is afforded for the motors. The return current comes back through the track bonded similarly to that for a direct-current system.

Signal systems are installed in a similar manner as in direct-current systems, with the difference that instead of the return current being direct current and an alternating current being used for operation of the signals, the return current is an alternating current of low frequency and a high-frequency alternating current (which will not pass the bonds at the end of the block) is used for the operation of the signal system.

As the series-commutating single-phase motor is really a high-grade direct-current motor, single-phase motive apparatus can be used on direct current by the addition of the necessary direct-current controlling apparatus, and it is customary for single-phase systems to operate on direct current through the portions of their line where the high-voltage alternating current would meet with objection from the local authorities, or would be considered dangerous to install.

Single-phase motors may be either of the series-commutating or of the repulsion type.

The advantages claimed by the advocates of this type of installation are its ready facilities for transmission; the obviation of third rails with resultant complications in yards; the use of one wire as opposed to two, on three-phase systems; the affording of an efficient voltage control, thereby allowing the power output to be directly proportional to the load; the motors can be wound for low voltage and the same transformer for dropping the voltage may be made to afford the voltage control; motors readily adjust themselves to the speeds of other motors with little unbalancing; the limits as to control of voltage are removed;

rheostatic losses are avoided; sub-stations are avoided with their attendant expenses for labor and upkeep; danger of electrolysis by return currents is avoided; there is a decreased cost of line copper and generally a decreased total cost for the installation of the system, thus affording a reduction in carrying charges; the efficiencies of static transformers hold over a wider range than those of rotaries; an adaptability to frequent and violently fluctuating loads; greater facility for extension of the electrification.

The disadvantages are the additional weight of rolling-stock; the greater complication of rolling-stock leading to less efficient and more expensive maintenance; the complication of the overhead line and the adoption of a system of conductor-installation which it is claimed will be shorter lived and will demand a larger expenditure for daily maintenance than a third-rail system; a consumption of more power at the car itself and somewhat higher cost of main power-station per kilowatt capacity; the carrying of an active electro-motive force between field turns; possible interference with adjacent telephone and telegraph circuits. There are also alleged against this system the troubles to which overhead conductors are liable, such as interference from wind, lightning, sleet, and snow; structural weakness of supporting apparatus; insulator failures; outside interference from falling trees or malicious persons; and a possibility of a derailment knocking out the supports from the ends of the bridges. The same objections are brought against overhead transmission lines for direct-current systems and similar objections to underground cable installation for transmission lines of direct-current systems, such as the depreciation of cable sheaths from electrolysis, mechanical injury to cables, gas explosions in manholes and capacity effects from local conditions causing extraordinarily high voltages.

The operating objections to such a system are that the overhead conductors may be in the way of a boom or derrick in wrecking operations; it is difficult to inspect, and more exposed to corrosion from locomotive gases, where steam and electricity are used over the same track; it may be a source of danger to the men on top of the cars and the collection of the current by means of a pantagraph, as usually practiced, makes it exceedingly difficult to install ticklers to give warning to trainmen on the tops of cars of their approach to low overhead structures; and the dangling end of a broken wire may be a menace to the public.

The objections arising from the possibility of derangement and of structural weaknesses are not very well taken, since it is customary to design the overhead structure with very large factors of safety to provide for adverse conditions. Thus, the New Haven designed its overhead system to be safe under all conditions, the cables being calculated of sufficient strength so that, should they be sheathed in ice one-half inch thick all around, a stress of only one-sixth of the ultimate stress would be set up in them; and the stresses due to wind have been figured on a basis of wind pressures of 16⅔ pounds per square foot projected surface for cables and 25 pounds per square foot normal surface for flat surfaces, allowance being made for double wind pressure in summer-time. The parts which may deteriorate rapidly are the least expensive parts of the installation, so that even a very large deterioration will not be prohibitively expensive. In a three-phase installation which has been in operation in Europe for several years, the maintenance cost of the line-construction has been $140 per mile per annum, and this for two trolley wires instead of one used for a single-phase installation.

Danger to men on top of cars from contact with the working conductor is obviated by placing these conductors so high above the track that they are well above a man's height, the standard position being about twenty-two feet above the rails. Danger from dangling wires should not be very great, as the wires are supported from the messenger at intervals of ten feet and the tendency will be for the hangers to hold the wire on each side of the break, so that unless the hanger gives way, a 10-foot length of wire at a maximum, dangling from a 22-foot height might be reasonably expected to give a 12-foot clearance of the track. In the case of several hangers giving away and a considerable section of the wire falling to the ground, with the high voltage used the rush of current would be so enormous and so sudden that the circuit-breakers would probably go out instantly and the current be cut off from the wire. In case of a live wire falling and coming in contact with a car-body, with the precaution of a thorough grounding of the roof of the car through the axles to the rails (as is customary with the alternating current installations in Europe), the risk to passengers will be reduced to a minimum. The probability of such a contact is small, since the chances of a car being directly under a broken wire are small.

While single phase installations have had their growth almost entirely within the last four years, this system is becoming particularly popular, and the present successful operation of a number of systems so equipped places it out of the experimental stage. The heaviest application of this system is that on the New Haven railroad, with which system there were the full share of troubles incident to the development of any new type of apparatus, but these troubles have now been overcome and the system is under regular and reliable operation and at the time of our visit to the system, it was entirely satisfactory, according to the officials responsible for its operation. Unmerited criticism of the New Haven has come because of the necessity of hauling the heavier trains with two electric locomotives, it being alleged that it shows a failure of the system to meet operating conditions. Inasmuch as the majority of the New Haven trains were light trains, the locomotive was chosen of the most economical type to haul these trains, with the expectation that the heavier trains would be handled by double-heading. When the electrification plans of this road were first announced and before the locomotives were ordered, it was stated that locomotives would be provided "capable of hauling a 200-ton train at a schedule speed of 26 miles per hour in local service, stopping every $2\frac{2}{10}$ miles, and that for heavier trains two locomotives would be provided," and when the first of these locomotives was tested and the locomotive actually hauled a 294-ton train under the 200-ton requirements, the satisfactory showing of the locomotive was generally commented upon. (See Street Railway Journal, August 24, 1907.) When it was announced before the locomotives were built that the heavier trains would be double-headed, adverse criticism of the locomotives for doing precisely as they were designed is very much out of place.

The steam railroad electrifications using the single-phase system in the United States are:

- New York, New Haven & Hartford.
- Sarnia Tunnel, Grand Trunk railway.
- Annapolis, Washington & Baltimore.
- Baltimore & Annapolis Short Line.
- Erie.
- Visalia & Lemon Grove (subsidiary to the Southern Pacific).

Trolley lines:

- Glen Cove (owned by the Long Island).
- Indianapolis and Indiana Traction Company (direct-current replaced by single-phase).
- Ft. Wayne, Decatur & Springfield.
- Spokane & Inland Empire System.
- Warren & Jamestown.
- Bloomington, Pontiac & Joliet.
- Syracuse, Lake Shore & Northern.
- Vallejo, Benicia & Napa Valley.
- Westmoreland County Street Railway.
- Atlanta & Northern.

Chicago & Milwaukee.
Illinois Traction Company.
Pittsburgh & Butler Traction Company.
Milwaukee Electric Railway and Light (Oconomowoc line).
Chicago, Lake Shore and South Bend.

Steam-road electrifications in Europe:

London, Brighton & South Coast.
Midland railway.
Seebach Wettingen.
Valle Maggia.
Spindlersfeld-Niederschoenweide.
Hamburg, Altona, Blankenese.
Vienna-Baden.
Swedish government railways.
Borinage.

Miscellaneous:

Hamburg City Interurban.
Menzel.
Stubaitalbahn.
Windsor, Essex & Lake Shore.
Rome-Civita-Castellana.

Three-Phase Systems.— The first development of alternating-current traction applied to heavy railroads was with three-phase apparatus, because a satisfactory type of railway motor was devised for three-phase working, before the builders of electrical apparatus undertook the construction of single-phase railway motors. The advantages as to lessened first cost because of absence of sub-stations and rotary transforming apparatus which are afforded by single-phase installation, are also available with three-phase apparatus. It has also proven attractive to European engineers because a number of European electrifications have been on heavy grades where recuperative working would be advantageous. The three-phase motors upon the line act as a sort of fly-wheel and store up or give back energy at times. Running on down grade the motor will generate and feed current back into the line, and in case of a sudden load coming on the power-house generators, the electric locomotives or motor cars in motion will restore a part of the current to the line and thereby make the load upon the power-house generators very smooth.

Except for the electrification of tunnels and mountain grades, for which it possesses a peculiar adaptability, three-phase equipment is objected to in this country because of the poor starting torque of the motors, because of objection to two overhead conductors in place of one, and because the three-phase motor runs at the same speed, regardless of grade, and allows little or no opportunity to make up lost time for a late train. Such motors would probably also be objectionable for electric locomotives exposed to very severe conditions as the variation of drive-wheel diameters commonly found with the drive-wheels of ordinary locomotives would throw the motors out of synchronism, and result in an objectionable unbalancing of the load between the motors on the several trucks.

The equipment of three-phase roads is similar to that of single-phase roads. Three-phase power is generated in a central power-plant, and either delivered direct into the working conductors at the voltage at which it is generated, or it is carried to sub-stations along the line where the voltage is transformed by stationary transformers to the line voltage and there delivered into the line. Two phases of the current are carried in two overhead wires, the third phase is provided for by the continuously bonded track rails. The conductors may be either directly attached to overhead bridges, supported from same by a single catenary carried by a cross-catenary suspension between side poles, or carried by a span-wire or bracket-arm construction similar to street-railway-trolley practice. The transforming apparatus is usually carried on the motor car or locomotive, although a low-line voltage may be used and the separate sections of the line fed from stationary transformers in sub-stations at the motor voltage. The so-called cataract control takes the place of the series parallel control in direct-current working, the stator of one motor being connected to the rotor of the second. The use of two overhead wires is liable to make crossings, turnouts, and yards complicated. It is probable, however, that such complication at a good many points could be obviated by the dropping out of one wire over such a crossing or turnout, since the three-phase motor will continue to run, although unbalanced, with one phase dead. Where three-phase systems enter cities, direct-current working may be adopted for the section through the city. This, for instances, has been done with the Lake Ontario & Port Stanley, a street-railway three-phase installation in Canada.

About the only three-phase electrification in the United States is the electrification of the Cascade tunnel on the Great Northern railway, at present under construction.

The most important three-phase system abroad is that employed on the Valtellina railway, a part of the Adriatic line in northern Italy.

This electrification comprises 67 miles of road at present, and is being extended. Amongst three-phase installations may be mentioned:

Great Northern (Cascade Tunnel).	
Lake Ontario & Port Stanley.	
London & St. Thomas.	
Valtellina	67 miles.
Burgdorf-Thun	25 "
Berlin Zossen	14 "
Stansstadt-Engelberg	14 "
Zermatt-Gornergratt	6 "
Jungfrau.	
Simplon Tunnel.	
St. Gothard.	
Experimental track Wollersdorf Arsenal, Austria.	
Arlberg Tunnel, Austria.	

Ward Leonard System.— In this system, instead of putting a rotary converter in a sub-station, the rotary is carried on the locomotive itself, the direct current from the rotary being used to operate standard direct-current locomotive equipment. While it saves transmission losses and affords smooth starting, requires only one conductor, the regulation of torque is good and electric braking is possible, the weight of the motor generator set, it would seem, would make the locomotive abnormally heavy for its power and the cost prohibitively high. For moderate-powered locomotives it would perhaps have a certain field, but to install an equipment of, say, the equivalent power of the New York Central locomotives would lead to an extremely cumbersome machine. It is probable that with such a locomotive, a tender of about the same size as the present New York Central locomotive bodies would have to be carried along to contain the motor generator set. There is this to be said, however, that the system has not had a very extensive application, which would lead to a material cutting down of weights and possibly a shaping up of the apparatus into practicable form for large sizes. Experiments are now being made with this system on the Seebach-Wettengen line in Switzerland, and when their results are published the capability of this system can be better judged.

Storage Batteries.— From time to time experiments have been made upon storage-battery motor cars and locomotives. These look attractive because of affording a self-contained unit which could be utilized on existing railway lines without any investment for line equipment. They also offer fields for economy in the possibility of avoiding rheostatic losses by using voltage regulation from different battery combinations and also the possibility of recuperative charging while going down hill or coming to a stop. The earliest electrical experiments were with storage-battery apparatus. In 1893, the Chemins de Fer du Nord constructed a storage-battery locomotive with which they hoped to haul their trains through the tunnel into their Paris terminal. The locomotive weighed 46 tons, of which 19 tons were battery, and was equipped with four 30-horse-power motors. The Belgium railways made experiments in 1894 with a 100-horse-power motor car equipped with batteries, but the equipment was not well chosen and the experiment was a failure. The Royal Bavarian railways, in 1896, inaugurated a service of storage-battery cars as an auxiliary to their steam-railway service on their Worms-Ludwigshafen-Weisstadt line. On the Milan Monza line in Italy, in 1899, a motor-car service supplied by storage batteries was put on to stimulate and develop local traffic. It worked fairly satisfactorily from an operating point of view, although the necessity of charging the batteries kept the cars within the city limits most of the time; but from an economic point of view, the results were not satisfactory, as maintenance was very high. The Rete Adriatica (by whom the Valtellina line is worked) put into service in November, 1900, a regular storage-battery train service on the line from Bologna to San Felice and on the Modena to Poggio Rusco line, one-motor car hauling a number of trailers. The capacity of the batteries allowed a 60-mile run without recharging and a speed of 27 miles per hour was made. The idea was not to prove storage batteries available for full-line service, but to use it for experiment to secure an economical service on secondary and branch lines of limited movement. After being kept on three years, the service was taken off, the equipment abandoned, and return was made to steam traction. The Paris, Lyons, Mediterranean company made an experiment with an electric locomotive in 1897, of 610 horse-power, capable of hauling a trailing load, not including battery, of 101 tons. The locomotive weighed 90.3 tons, of which the tender carrying the battery weighed 45.8 tons. A storage-battery service was put on the line between Aja and Scheveningen. The Hungarian government put such a service on the Arad line. The Würtemberg government made a series of competitive tests between storage-battery cars, gasoline cars, and steam motor cars, maintaining each type of car in service for a period of several months. Besides these, a number of storage-battery experiments have been made on street-car systems, both in this country and abroad.

Storage-battery traction was first advocated for heavy traction, later, for service on light and unfrequented lines; and lastly, as a means of putting on a cheaply installed, cheaply run, and more frequent service on lines upon which it was believed enough traffic could be stimulated to justify electrification with standard apparatus, the storage-battery car being used in the meantime as a means of trying this out.

The disadvantages of a storage-battery installation are that the batteries necessary to afford the requisite power are extremely heavy and form from one-eighth to one-third the weight of the entire train; that they are expensive in first cost; that they lack elasticity, the very violent fluctuations to which they are exposed in railway working rapidly running down and deteriorating the battery; the cost of maintenance of batteries is extremely high because of the vibrations to which they are subjected from passing over switches, around curves, etc.; that they afford a very low efficiency because of the severe conditions under which they are worked and because their rapid deterioration because of the adverse conditions under which they must be maintained in a locomotive installation rapidly pulls down their efficiency from that which they possess when new. This last was very well shown in the Würtemberg experiments, the energy consumption being 40¼ watt-hours per ton mile when the installation was new, while the average for fifteen months was 61¼ watt-hours per ton mile. The results of the Würtemberg experiments are given in the appended table.

	Daimler Benzine	Sarpollet Steam	Accumulator	Ganz Steam
Approximate weight car in tons....	15.7	22.1	35.4	14.3
Number seats.................	24	32	56	33
Average cost of car...........	$7517	$7517	....	$6547
Daily performance, miles.......	56.4	54	54	120
Fuel cost per mile.............	$0.0352	$0.0302	....	$0.027
Cost lubricants per mile.......	$0.0025	$0.0023	....	$0.001
Total cost supplies per mile.....	$0.0377	$0.0325	$0.1042	$0.028
" " " per seat mile	$0.00157	$0.0098	$0.01768	$0.0082

Gasoline and Gasoline-Electric Cars.— A good deal of experimenting has been done with motor cars driven by gasoline engines, either with a straight gasoline equipment or a gasoline-electric equipment,— that is, the cars may be driven simply from a gasoline engine driving the trucks through gearing or by sprocket chains, or they may be driven by electric motors which are supplied with current from a gasoline engine driving a dynamo within the car.

The advantages of these cars are that they demand little attention, and it is possible for the cars to carry a crew of two men only. The fuel consumption stops whenever the car stops; the car is ready for operation at a moment's notice. The reason for employing the gasoline-electric drive rather than the straight gasoline is, that the car is under much better control, being easily started and stopped, and with a large range of speed variation. The gasoline-electric car should be somewhat more reliable than the straight gasoline car, since the driving mechanism is simpler. A further refinement in the case of a gasoline-electric car consists of the installation of a storage battery to steady the load on the engine and this battery may be large enough to afford sufficient current to enable the motor car to get to its destination, should the engine break down. The economy in the battery installation lies in the more economical working of the engine, due to a steadier load, and to the ability to use a smaller engine and generator, supplying the peak from the battery.

The Union Pacific has built and is building a large number of gasoline cars which are in successful operation for branch-line and intermediate-traffic operation in the West. The St. Joseph Valley Traction Company and the Delaware & Hudson are using gasoline electric equipment, the former with a storage-battery attachment.

These devices have been studied in their relation to the possible handling of suburban traffic. While their use would do away with the smoke nuisance, it is not believed that they are capable of reaching a heavy enough development to afford material assistance to the railroads, in coping with the Chicago situation. They, in company with steam-motor cars, afford a cheaply installed and economically run service for branch and unfrequented lines, but they are a small proposition at the most. To build them in sizes capable of handling the heavy trains would demand prohibitive weights. While gasoline engines have been built with extremely light weights per horse-power, the experience of engine builders is that, to secure the greatest reliability, internal combustion engines must be made at least 50% heavier than steam engines of equal capacity, and they must be fastened down very rigidly. Thus, the gas engines built by one of the large engine builders in the country run uniformly around 50% above the weights of steam engines. We believe that their development in large sizes would lead to machines like the Heilman locomotive, built by the Compagnie de l'Ouest in France, which sought to obtain the advantages of electrical traction by carrying a complete electrical power-plant on the frame of the locomotive in addition to driving motors. The locomotive was equipped with compound engines and two generators, in addition to the boilers, motor equipment, etc. In order to provide a 1200 horse-power equipment, a machine weighing 150 tons was built, at a cost of $54,000.

Gasoline cars and gasoline electric cars can afford an extremely valuable auxiliary service in giving a cheap passenger service to lightly patronized lines. They may also be used to great advantage as stimulators of traffic, and undoubtedly could be used successfully by putting a fast and frequent service of them on a line which it is believed would offer a favorable field for electrification, to ascertain whether the better service will give rise to a sufficiently dense traffic to support such electrification. Should a favorable result be shown, the line could then be electrified. That this is the trend, is shown by an item in the ELECTRIC RAILWAY JOURNAL of June 20, 1908, which states that the Missouri & Kansas Interurban Railway Company, operating a road between Kansas City, Missouri, and Olathe, Kansas, originally equipped with Strang gasoline cars, has now under consideration the electrification of its road to take care of the increasing traffic.

EXISTENT INSTALLATIONS OF ELECTRIC TRACTION

H. H. EVANS

We shall examine in this section the electrifications which are already in operation, which are under construction, and those for which plans have been adopted but actual construction work has not yet been begun. This will afford us a means of judging whether electrification has passed from an experimental to a practical state, whether the various features found in Chicago have been met with in electrifications already installed in other places, and we shall endeavor to go into the reasons and the results of these electrifications as far as information is at hand.

An examination of existent electrifications shows by their number, their magnitude, and their diversification and the length of time that they have been in operation, that electrification has passed from the experimental to the practical state. Such experimentation as is being done is done to determine which system of electrification is best adapted for certain conditions and not to see whether electrification in general is practicable;— *the choice is between systems and not a proving of the art.*

While the precise situation met with in Chicago has not been encountered in existing electrifications and while the volume of freight handled by electricity is small, there seems to be hardly a feature of the Chicago situation which has not been met in some place or other to a greater or less degree in existent electrifications. So far as ability to handle a dense traffic is concerned, we believe that it is generally conceded that under electrical working a greater number of trains can be handled under a given trackage, than under any other system. Thus, the schedule of the New York Subway requires thirty eight-car trains to be handled over one track in an hour, and during the rush hours the headway is one minute and forty seconds, with a possibility of improvement as soon as the cars have been altered to facilitate the loading and unloading of passengers. As the Subway is a four-track road, to send 8-car trains over the tracks on 1 minute, 40 seconds headway would mean a possible 144 8-car trains past a given point in an hour, or 1152 cars.

Now the Illinois Central has the heaviest similar traffic in Chicago, where close on to 1000 cars are handled on four tracks in 24 hours, so that a system which is capable of hauling the entire 24-hour requirement in one hour, can hardly be said to lack the requisite capacity.

As to speed, the fastest speed on record is that made during the Berlin-Zossen tests, when 130 miles per hour was made by an electrically propelled train. Such a speed as this is entirely impracticable, but at the same time it demonstrates the capabilities of electric traction in this direction.

As to train weights, electrical traction is being installed in several points, because it is capable of handling heavier trains than is possible by steam.

As to mechanical difficulties of installation of third-rail or other conductors in complicated yards we would call attention to the plate of the track lay-out in the New York Central's terminal, now in process of construction, which plate will be found inserted at the end of this report. (Reprinted from "Engineering News.")

We shall first examine the existent electrifications in the United States and then those which have been installed in various foreign countries.

UNITED STATES.

The first electrification of a standard steam road in the United States was that of the Nantasket Beach branch of the New York, New Haven & Hartford railway. This was put into service on the 30th of June, 1895, a motor-car passenger service for the hauling of excursion crowds being installed. It was followed closely by the electrification of the Baltimore & Ohio Tunnel through the city of Baltimore, which was put into service August, 1895, and was the first piece of main line electrified in the world. The new Haven extended its electrification to other branches, and shortly after this, the Boston & Maine built an electrical section into Concord; the Pennsylvania railway electrified its Baltimore & Mt. Holly branch about the same time.

After this, the electrification movement began to be more or less general. Lines which were in competition with street-railway and interurban roads, were first electrified in order to meet this competition, and later, suburban and interurban sections of road were electrified. Finally came the major electrifications, such as those of the Long Island, New York Central, and the New Haven roads.

The motives for electrification have been various. In some cases, where coal was high or water power available, roads have been electrified purely from motives of economy. In other cases, electrification has been resorted to to get rid of the smoke nuisance. Again, sections of road have been electrified to meet certain railway or interurban competition;

and in at least one case it is given out that the reason for electrification was to secure a larger possible traffic movement. In some cases electric roads have secured control of steam railroads and electrified them as a part of their system and in other cases steam railroads have acquired control of electric interurban properties and electrified a portion of the steam road to form a link in such a system.

NEW YORK CENTRAL & HUDSON RIVER RAILWAY.

The New York Central electrification was undertaken primarily to get rid of the smoke nuisance, but after the electrification of this terminal was determined upon, the scope of the work was extended so as to secure a number of advantages to the railroad. The passenger entrance of the New York Central into New York City is by means of a four-track line, which passes from the junction of two divisions of the railroad just north of the Harlem River in an almost north and south line to the terminal station at Park Avenue and Forty-second Street, a little below the center of the Island. The Harlem River bridge was formerly a source of a good deal of annoyance because of the necessity of opening the draw for the passage of almost all kinds of craft. About ten years ago these interruptions became so serious that the bridge was raised high enough to permit the passage of all classes of vessels, except those with spars or high upper works, without opening the draw. This necessitated the elevation of the tracks from the Harlem River to the entrance of the Park Avenue Tunnel at Ninety-ninth Street. From Ninety-ninth Street south to Fifty-sixth Street extends a tunnel under Park Avenue, with occasional ventilation louvres to the street above. From Fifty-sixth Street south to the terminal station, the tracks lead through a sunken terminal yard. Just north of the Harlem River at Mott Haven, there is a junction of the main line of the railroad (which comes down the east side of the Harlem River to the mouth of that river and skirts the shore of the Harlem beneath the bluffs to Mott Haven), and the Harlem division of the railroad, extending north about 130 miles to Chatham, New York,— both being four-track lines. Coming over the Harlem division, which it joins at Woodlawn, 12 miles from Grand Central Station, is the main traffic of the New York, New Haven & Hartford Railroad, this road having a trackage agreement with the New York Central. There is, thus, practically a junction just north of the terminal tracks of three four-track lines carrying a very heavy traffic. The traffic at the inception of the electrification amounted to about 650 trains per day, and this has been increased since the electrification.

There are, in addition to these lines described, but not included in the electrification at the present time (although their electrification is contemplated), a freight line leaving the main line at Spuyten Duyvil, at the confluence of the Harlem and Hudson Rivers, there crossing the Hudson River and running thence along the western shore line of Manhattan Island to a freight terminal at Thirtieth Street and Ninth Avenue, and thence extending south along West Street partly on tracks used by a horse street-car line to within about a mile of the Battery, and a passenger line known as the Putnam division running parallel to and about midway between the two electrified lines we have described, and crossing the Harlem River at One Hundred Fifty-ninth Street, where it makes a connection with the Interborough Rapid Transit Company's lines.

The weakest point in the New York terminal has been the Park Avenue Tunnel. It has acted as a throttle upon the whole system and has been a menace to the travelling public and a source of great discomfort. The small terminal yard and the junction at Mott Haven were also throttle points in the system. The public became greatly dissatisfied with the operation of this tunnel by steam locomotives, and several serious accidents in the tunnel brought home to everybody the need of providing a means of operation which would do away with the smoke nuisance inside the tunnel. The railroad worked out a number of projects for amelioration of the conditions, installed several improved signal devices in order to make its operation more safe, and finally turned to the consideration of electrification, partly in order to get rid of the smoke nuisance and partly to afford an increased terminal and traffic capacity.

In 1901 they had a commission make a study of the feasibility of electrifying their system between the Grand Central Station and the Harlem River. Meantime, property owners adjacent to the property had organized and were active in agitation for legislation to compel the use of electric trains in the tunnel. Public sentiment was crystallized by the serious accident of January 8, 1902, and the demands for the electrification of the road were so insistent that a legislative act was finally passed in 1903, requiring the electrification of the terminal within five years.

When the New York Central made their plans for electrification, they adopted a very comprehensive plan designed to largely better their terminal and traffic facilities. They provided for an increase in ground area in terminal of 178% and in track length of 151%, their storage tracks being increased 453% so as to enable them to store trains at the terminal instead of having to haul all incoming trains out to the yards beyond the Harlem River for storage. They also decided to extend the scope of the electrification to include their suburban service, carrying the installation under the present plans to Croton on the Hudson division, 34 miles from Grand Central Station, and to North White Plains on the Harlem division, 24 miles distant. Mere compliance with the law would have only required the electrification out as far as Mott Haven, a distance of 5⅓ miles from the station, or had it been possible to make the changes in motor power in the limited space of the terminal, the mere electrification of the two-mile length of Park Avenue Tunnel would have met the requirements of the legislature.

In addition to the electrification of their main line and suburban traffic, an extensive enlargement of their terminal yard was undertaken. Additional tracks were laid within the electric zone and a number of improvements made in alignment, trackage, and station plant. The most notable improvement in alignment is the Marble Hill cut-off, where an S-shaped curve is obviated by a fill and a tunnel. A large amount of track elevation and yard construction has been undertaken, suburban stations have been rebuilt, and the necessary plant built for the care of electrical apparatus. In addition, a new and a larger office building is being built to replace the Grand Central Station. The terminal is to have tracks on two levels, the suburban terminal being practically separate from the other terminal and located on a lower level. The streets which were formerly interrupted at the terminal yard, are being carried across on steel bridge work and eventually the entire terminal yard will be covered with office buildings or other revenue-producing property, the cars running underneath them. Thus a large proportion of very valuable ground will be reclaimed for general use.

The freight tracks have not yet been electrified. The line which we have already described along the western side of the island is the only New York City line carrying freight, which enters Manhattan Island; the bulk of the freight goes to the New Jersey shore, whence it is lightered to its destination. These tracks on the western side of the island have always been a matter of a good deal of dispute in New York City. They could be made of a great deal more service than they at present afford, were the railroad given a free hand in their development. There has been a tendency to hamper them as much as possible because they are somewhat in the nature of a nuisance and because the people have serious objections to the railroad monopolizing the water front. Before the Pennsylvania tunnels, under the Hudson River, were undertaken, a plan was made for building a large suspension bridge across the Hudson River, upon which the roads would be brought into New York. A large amount of the preliminary engineering work for this bridge was done, the permission of the War Department was obtained for its building and a bill providing for its charter passed the state legislature. The charter provided for an elevated freight railroad along the western water front of Manhattan Island as an approach to the bridge and would have given the bridge company a virtual monopoly. Because of the public objection to this feature, the bridge bill was vetoed by the governor of New York state. So it has been with most attempts to provide a better freight service for the docks along the New York water front. We have it on very good authority that the New York Central is extremely desirous of developing this line. They have made a proposition to the Public Service Commission, if we can believe the reports generally published in the New York press, to build a subway along the western shore of the island and put their tracks in it and electrify them, provided certain concessions are given, one of which, we believe, is an extension of the franchise to give them freight-carrying privileges to the extreme end of the island; and another, to allow them to tie these tracks through a cross-town subway, to the trackage in the Grand Central terminal. By so doing they would be able to offer greatly increased freight facilities and they would be enabled to bring their passenger trains from the Hudson division, south along these tracks and into the Grand Central Station, thereby relieving the congestion at the junction of these tracks with the Harlem division tracks at Mott Haven, which exists at present. Their power-house is of sufficient capacity to handle not only their present traffic, but this freight traffic as well, so it is reasonable to conclude that the eventual handling of this freight traffic, as announced in the press and as we have it from certain other sources, is contemplated by the New York Central.

The initial electric zone is 17 miles long; the section from Grand Central Station to Wakefield 13 miles and from Mott Haven to Kingsbridge, 4 miles long. In this there are 73 miles of main and 12 miles of yard track, or 85 miles of track. In the entire zone there will be 52 miles of line in which there will be 224 miles of main track and 68 miles of yard track, or a total trackage of 292 miles of electrified track.

The power-stations are in duplicate, stations similar in essential respects being installed at Yonkers and at Port Morris. Each will have an ultimate capacity of 30,000 kilowatts, the present capacity being

20,000. The turbine room is 69 feet by 232 feet and at present contains four 5,000-kilowatt Curtis turbo-generator sets. Two 150-kilowatt turbo-generator exciter sets and one 150-kilowatt motor generator exciter set are provided for each station. The boiler-rooms are 88′ x 232′ and will ultimately contain each twenty-four 625-horse-power Babcock and Wilcox boilers, of which 16 are at present installed. Over each boiler-room is a coal bunker with a capacity of 3,500 tons, the usual coal unloading and conveying apparatus being provided. An operating gallery runs across the end of the turbine-room, but the switch-houses are entirely separate from the main buildings. The separate switch-house building contains also a power-station sub-station partitioned off from the switch gear. An auxiliary board in the switch-house allows the main operating board to be cut out if necessary. There is a complete isolation of the alternating-current and direct-current apparatus and all high-tension apparatus is installed in the basement under the switch-house, to which only authorized persons have access. The power-stations are inter-connected so that either one can carry the entire load of the system. A large storage battery is installed in each sub-station, the storage battery capacity of the system being sufficient to carry the entire system for several hours in case of a shut-down at the power-house. The capacity of these batteries is as follows:

Sub-station Location	No. of Cells	Discharge rate 1 hour	No. Boosters
Gr. Central Station.........	318	4020 amperes	2
Mott Haven...............	318	3750 amperes	2
Kingsbridge...............	318	3000 amperes	2
Yonkers..................	318	2250 amperes	1
Irvington.................	318	2250 amperes	1
Ossining..................	318	2250 amperes	1
Bronx Park	318	2250 amperes	1
Searsdale.................	318	2250 amperes	1

The power is generated at 11,000 volts and transmitted to the various substations by duplicate systems of insulated copper cables inside the populous districts of the city and by bare, overhead wires carried on steel poles on the sections outside the city. The cables within the city are carried in ducts in the ground, in ducts within the side walls in the tunnel, or in pipe conduits on top of the enclosing walls of the elevation, as conditions demand. The direct-current feeders are carried in a similar manner as the high-tension transmission lines. At frequent intervals the feeders enter circuit-breaker houses where the current is carried through automatic circuit-breakers which interrupt the circuit in case of an abnormal flow of current, owing to short circuits or other causes. The alternating current, upon entering a sub-station, is transformed, from 11,000 to 450 volts by stationary transformers and the 450-volt current led into rotary converters, from which 660-volt direct current is fed into working conductors. In each station storage batteries are installed, as we have before mentioned, floating on the line, so that when current demands come in excess of the station capacity, the battery feeds into the working conductors and when the demand is below the station capacity, the excess current charges the battery. The substations are located as follows:

Location	Miles from Grand Central Station	Rotaries
Fifteenth St. & Lexington Ave.	.36	3–1500
Mott Haven Junction.	5–47	3–1500
Kingsbridge.	9.44	3–1000
Yonkers.	15.64	3–1000
Irvington.	22.11	3–1000
Ossining.	30.31	3–1000
Bronx Park.	9.3	3–1000
Scarsdale.	19.02	3–1000

The current is led from the sub-stations into the third rail, and connections from feeders are made into this rail at points where traffic is liable to be heavy or where too large a drop in voltage would otherwise be had. The rail is of the protected, under-running type originated by Messrs. Wilgus and Sprague and its operation has proved extremely satisfactory both as regards freedom from sleet troubles and its safety to the public. At intervals the rails are sectionalized and connection made past the break through a sectionalizing switch carried at the side of the track, the terminals from which are connected to the rail ends by the usual jumper cables. These sectionalizing switches enable a portion of the third rail to be cut out of the circuit in case there is work to be done. The return is by means of the track rails which are bonded together by bonds concealed under the fish-plates and the track cross-bonded at intervals through impedance bonds. The signals are worked by means of a 25-cycle alternating current of low voltage, the rails at abutting blocks being insulated from each other and the continuity of the track return kept by leading the current through impedance bonds around the insulated gap.

The transmission in the initial zone comprises 12 miles of conduit territory, 89 miles of cable in conduits, 6 miles of pole-line territory, 48 miles of cable on poles, 220 splicing-chambers, 9 circuit-breaker houses, 1 cable tower, 1,500,000 pounds of copper. In the entire zone there will be 16 miles of conduit, 97 miles of cable in conduits, 48 miles in pole lines, 344 miles of cables on poles, 382 splicing-chambers, 26 circuit-breaker houses, 3 cable towers, 3,000,000 pounds of copper. In the initial zone the working conductor comprises a 70-pound rail along 75 miles of track. There are 285 circuit-breakers and switches, 1,400 feet of jumpers, 43,000 track bonds. The whole terminal will have 285 miles of third rails, 5 miles of overhead construction, 450 switches, 37,000 feet of jumpers, 136,000 track bonds. The terminal will have a capacity of 12,000 cars when finished.

The equipment originally ordered comprised 35 locomotives for hauling the through trains and a suburban equipment of 125 motor cars and 65 trailers. The locomotives have a total weight of 94½ tons, measure 37 feet over all, 27 feet on wheel base, carry 68½ tons on the drivers and are equipped each with four 550-horse-power motors, making a total of 2,200 horse power for the motors, the overload capacity of the locomotive being 3,300 horse power. The motors are gearless, bi-polar motors with flat-pole faces and a large air gap so that changing of armatures is very readily effected and so that there is very little possibility of derangement from running or by operation. The locomotives are fitted with Sprague-General-Electric multiple-unit control so that they may be worked double-headed by one operator. They are fitted with collector shoes on both sides at both front and rear and with two pantagraphs on top which can be raised by air pressure and brought into contact with a working conductor carried on overhead frame work above portions of the track where intricacies of the lay-out interrupt the continuity of the third rail. The locomotives are fitted with an oil-fired steam boiler for heating the trains to which they are attached in winter time. The cars for suburban service are of steel throughout, measuring 62 feet over all. The motor cars are equipped with two 200-horse-power motors, or a total of 400 horse-power for the car. The motor car weighs 53 tons and the trailers weigh 44½ tons. Each has a seating capacity of 64. They are provided with steam and electric heat, are lighted both by electricity and by Pintsch gas and have rather an unusual feature in being provided with two electric fans for cooling them in summer-time. The cars accelerate at the rate of 1.2 miles per hour per second.

The actual work of construction on this system was begun in the spring of 1904, the work on the transmission lines and working conductors being started early in 1905. The electric service was started by running four trains out on November 11, 1906, an all-electric service was put on at the end of April 1907, and the last steam train was taken off the regular run on July 1, 1907. While the actual electrification of existent tracks into the terminal is complete, the outer zone of the electrification is still in process of installation and the very extensive terminal improvements are only partially completed.

Despite the disadvantage under which the system is working, a reduction in the expense of working, a reduction in the number of dead movements, and a reduction in the total minutes late per month of trains, have been effected. The locomotives are handling heavier loads than they figured upon originally. However, after a service lasting several hours, they only handle about one-half their short-time capacity on account of heating resistances. For switching service it has been found necessary to add additional resistance to the locomotives. We were assured by the officials that the operation of this terminal has been satisfactory and without serious derangement at any time. Their most serious difficulty was with a short circuit where sufficient current did not flow to open the circuit-breaker, the breakers being set to drop only when large quantities of current passed through them, on account of the requirements of heavy trains. This has been taken care of by carrying a pilot wire in the insulation of each cable. In the case of a short circuit, this pilot wire fuses and throws out an auxiliary breaker at the sub-station, when the main breaker is thrown out. An additional safety device has been installed in the tunnel in the shape of a cord along the tunnel wall. In case of accident, anyone, preferably the conductor, may pull this cord and cut off the current from the system so that there is little danger of the passengers suffering in case they abandon a train in the tunnel after a wreck. Anyone may cut off the current, but an order from the load-despatcher is required before it can be put back on. There has been no disorganization of the operating force incident to the electrification. The electric department is organized as a separate department whose function it is to deliver current to the train. Its relation to the regular force is much the same as that of a company which supplies us with electric light. The operating department simply puts its locomotives or motor cars out on the line and picks up the current for running,— operating under old rules and conditions to a large extent. A separate electrical right-of-way maintenance gang is used. There is no particular alteration of the maintenance system of the track. Secondary and freight tracks have not yet been electrified, for the reasons noted at the beginning of this section. There has been

Courtesy General Electric Co.

New York Central & Hudson River Railroad — First Electric Train leaving Grand Central Station, New York City — Third Rail in Foreground.

a very large insurance against interruption, there being practically a triplication of power supply. Two power-houses, each large enough to handle the full load, are provided and there is also sufficient battery capacity to take care of the full load for 24 hours. This was installed, according to the best information we could get, (1) to insure against every possible derangement; (2) to afford capacity enough to take care of freight traffic when freight trackage shall be electrified; (3) in expectation of having to supply the New Haven with a large amount of current. Up to the time of our visit, only two employees had been killed on account of the electrical equipment. The rail is very well protected and every possible safeguard adopted for the apparatus. At the station platforms, dummy guards are provided to keep people from coming in contact with the third-rail shoe.

Mr. Wilgus, in a paper read before the American Society of Civil Engineers, on this electrification, on March 18, 1908, stated that the electrification is fully accomplishing the purposes which led to its adoption, namely, "(1) abolition of nuisances incident to the steam locomotive, and (2) increased capacity of the Grand Central terminal a full year in advance of the date fixed by law, and in addition (3) the promise, with the completion of the changes, of a saving in the cost of operation of from 12% to 27%, after providing for increased capacity for electrification, and (4) the outlook for a large future growth of remunerative traffic and other sources of revenue attendant to the usage of electricity, much more than sufficient to provide for the increased capital charges for the other improvements."

Mr. Wilgus was later quoted in the Street Railway Journal of March 28, 1908, to the effect that the New York Central would save $200,000 a year by using their own power for lighting, and $114,000 a year by switching during non-peak loads. In the discussion of the paper of Mr. Wilgus above quoted, he closed his discussion with the statement that the system gives promise of substantial economies in operation which, it is believed, will approximate $750,000 annually when the whole electrification shall have been put into operation.

NEW YORK, NEW HAVEN & HARTFORD RAILWAY

This road is easily the pioneer in electrical traction applied to steam roads in the United States. The road has perhaps the largest proportion of passenger traffic to total traffic in the United States. It covers pretty thoroughly the southern part of New England, runs through a thickly populated territory, and has a number of towns of considerable population at short distances along its route. This railroad early had electrical roads enter into competition and electrified several of its branch lines partly to hold its traffic and partly as an experiment to determine the possibilities of electrical working applied to a road operated under steam-railroad conditions. Later, when its traffic route into the Grand Central terminal compelled it to provide for the operation of its trains into the terminal by electricity (on account of an act of the legislature), the New Haven did not content itself with merely providing for the terminal operation, but treated the question as a general problem and electrified its lines from their junction with the New York Central electrical zone out to Stamford, and it is the announced intention of the officials of this road to convert their entire system between New York and Boston into an electrical road.

In addition, the New Haven has seen the value of co-operation with local electric trolley roads in order that the same might serve as feeders for their main-line traffic and has entered into a policy of systematically acquiring the roads which drain the traffic adjacent to their territory and of working these roads as adjuncts to their system. The trend of the New Haven seems to be toward electrically equipping their line and operating all classes of traffic by electricity and possibly to utilizing certain portions of their track between towns for the passage of interurban cars from town to town, which, upon reaching the outskirts of a town, will enter the local street-railway tracks, thus landing the passenger at the door of the place to which he wishes to go. That they were early awake to the possibilities of electric traction is shown by the report of Charles P. Clark, president of this road in 1891,— that the only effectual way of checking electric-railway competition was to equip the lines affected with electric traction. He advocated equipping a branch line to demonstrate what could be done with electric traction on a standard steam railroad.

In the year 1894, the management of the New Haven authorized the introduction of electrification on their Nantasket Beach branch, and this was the first installation of electric traction on a standard steam road. The Nantasket Beach line was a line debouching from one of their secondary lines running southeast from Boston, then north up a peninsula along Nantasket Beach, a seaside resort. The electrification of this line was completed on May 20, 1895. It comprised 6.95 miles of double track, extending from Nantasket Junction to Pemberton. It was equipped with overhead-trolley center-pole-bracket construction originally, on which a 600-volt direct current was carried. The power-house was located at the middle of the route, and contained two 250 horse-power Green-Corliss engines. The rolling-stock consisted of standard passenger coaches equipped with motors hauling a variable number of trailers. The original equipment comprised 6 motor passenger cars and 4 motor express cars, the trailing equipment being their standard steam equipment. Some cars were equipped with two and others with four 125 horse-power motors, the motor cars being capable of hauling a train weighing from 400 to 500 tons total at a maximum speed of about 35 miles an hour, and at an average speed of about 16 miles an hour. Both steam and electric trains were used on the line. The results being satisfactory, it was decided to electrify other branches and in 1896 the Nantasket and East Weymouth line was constructed. Later the electrification was extended from Nantasket Junction to Braintree, and in 1899, from Braintree to Cohasset. The latter line extended over a route 11.51 miles in length and was a double-track road. A third rail was installed, the third rail of A-section being carried on wooden insulators in the middle of the track. The rail was interrupted at crossings and an overhead trolley installed at such points. Standard passenger coaches equipped with motors were employed upon the line. The operation of the Nantasket Junction and Braintree section was somewhat troublesome because the track was used both by steam and electric trains. The insulation was poor, there was considerable leakage and the ashes from the locomotives were being continually dumped on the third rail. The entire mileage of this section to Nantasket Beach and tributary country was 40 miles, the route length being 20 miles. In 1904, the third rail was taken up on the Nantasket Junction and Braintree section and the line given over to steam traction.

The high-speed trolley lines along the beach (owned by the New Haven) have been retained, however. Considerable of their traffic fell off when Nantasket Beach was acquired by the Commonwealth of Massachusetts. This beach was turned into a public reserve, and a good deal of the attractiveness to excursion crowds was removed by the ousting of various amusement enterprises. Consequently, in addition to the electrical system being antiquated, it is probable that the traffic decreased so largely that it no longer was dense enough to support an electrical system.

Because of the success of the Nantasket Beach electrification, the Berlin-New Britain branch of the New Haven road was electrified, the substitution being started in March, 1897, and completed in 1898. This line, as originally installed, was about 12 miles long, a 3-mile double-track section being first equipped. A third rail carried in the middle of the track was installed, the rail being broken at crossings. Their first equipment comprised 5 electric motor coaches hauling standard passenger trailers. In 1905, objection was raised by the authorities of New Britain to the third rail as it was regarded as a menace to public safety and the railroad was compelled to discontinue its use in August 1906, by a court decree. As the rail was totally unprotected, the authorities were probably justified in having it removed. It would be interesting to know what would have been the attitude of the authorities had a protected third rail been substituted.

In 1895, the section between Hartford and Bristol, Connecticut, was electrified, a double-track line of 18.6 miles being equipped. An unprotected third rail similar to their other installations was adopted. In June 1905, this third rail was removed as it was considered a menace to public safety and as it was also high in upkeep.

In 1898, the electrification of their Stamford-New Caanan branch was undertaken by the New Haven, comprising 8 miles of single track. An overhead-trolley system was installed operating on direct current, a pole-bracket construction being adopted, standard passenger coaches equipped with motors being put on the line. In the summer of 1908, this line was changed to a single-phase installation, their standard voltage of 11,000 carried on the main line being adopted for the system, and a single-catenary-suspension system being adopted. It is apparently their policy to change such systems into single-phase systems as fast as their main-line electrification comes into connection with them. Although the installations on these lines were primitive, their working was successful and drew general attention to the possibilities of electric traction applied to steam railways.

In 1900, Col. Heft, their electrical engineer, read a paper before the American Institute of Electrical Engineers, in which he discussed electric traction for steam railways and gave the results which had been obtained on these branches. Notwithstanding an increase in the number of stops, there was an increase in the schedule speed. On the Nantasket Beach line the figures were:

	Length of Line, miles	No. of Stations	Schedule Time, minutes	Average Speed, miles, per hour
Steam, 1894.......	6.95	10	25–35	16.7 to 11.9
Electric, 1897.....	6.95	16	21	19.81

The traffic under the better facilities afforded, increased as follows:

Nantasket Beach........	304,292	702,419
Highland................	387,695	1,060,617
Berlin..................	267,936	241,207
New Canaan............	98,302	184,728

The cost per train mile on the Berlin and Highland Division was given as follows:

	Daily Train Miles	Cost per Train Mile
Berlin Division.................	66	30.3 cents
Highland Division..............	737	12.5 cents

The motive-power cost on these divisions under electric operation and under steam operation is as follows, this cost including the operation and the maintenance of power-station, the maintenance of motors and of car-equipment, the supply of oil, grease, and water, and the wages paid at the power-house:

Steam locomotive	0.19 to 0.24 per train mile
Highland Division.......	0.0604 per train mile
Nantasket Beach........	0.1441 per train mile
New Canaan............	0.0783 per train mile
Berlin..................	0.1406 per train mile

Total cost of operation per train mile with motor cars was:

Berlin..................	0.3032 per train mile
Highland................	0.1255 per train mile
Nantasket Beach........	0.2925 per train mile
New Canaan............	0.1754 per train mile

And the cost for train labor:

Berlin..................	0.18 per train mile
Highland................	0.027 per train mile
Nantasket Beach	0.0829 per train mile
New Canaan............	0.063 per train mile
Steam (about)..........	0.12 per train mile

At the time of the undertaking of the electrification of its main line, the New Haven had in operation under electricity the following mileage:

Division	Total Miles Single Track	Mileage Between Terminals
Providence, Warren & Bristol.............	44	33
Stamford & New Canaan.................	9	8
Nantasket Beach..........................	40	20
Hartford & Bristol........................	26	20

Following the inception of the New York Central electrification into its Grand Central terminal, the New Haven road announced that it would install an electrical system on its main line. It was proposed to provide for the electrification of six tracks, the line being composed of four tracks at the time. The proposed electrification was to cover the line from the entrance of the New Haven trains into the New York Central zone at Woodlawn (12.03 miles from Grand Central Station) out to Stamford (33.48 miles from Grand Central Station), extending over 21.45 miles of four-track line. This was carried out as proposed.

The single-phase system was used on this installation and it is the largest and best installation of this type in the world. Power is generated at a turbine station located at Cos Cob, near the eastern end of the electrification. The station is equipped with three 3,000-kilowatt 11,000-volt 25-cycle Parsons-Westinghouse turbo-generator sets, generating single-phase current for supply to the working conductors. A fourth generating set supplying three-phase current for the power-circuit has been recently added. The working conductors are carried from a double-catenary suspension on steel bridges spanning the tracks. These bridges are installed at intervals of 300 feet on tangents and at less intervals on curves as local conditions demand. They are of steel lattice-work construction, the posts at the ends being supported on concrete footings. The bridges for the greater part of the distance are made long enough to include six tracks, although only four tracks are at present installed. In some places the bridge only covers four tracks, while spans of as many as twelve tracks are covered by bridge work where demanded. Poles are installed on curves with pull-overs attached where required. The bridges carry, at their upper surface, insulators on which the messanger cables supporting the working conductors are carried. Two steel-wire messenger cables are used for the suspension of each working conductor. The messengers are of $\frac{9}{16}$ inch 7-strand steel cable having an ultimate strength of 200,000 pounds per square inch, each strand being galvanized. The complete cable has a strength of 33,800 pounds. The cables are pulled up so that the sag at the mean temperature is 6 feet in 300 feet length between bridges. The working conductor is suspended over the center of the track from the two messengers by triangular hangers clamped at the apexes to the messenger wires and to the trolley wire. The messengers thus serve to prevent lateral sway as well as to limit vertical motion. The working conductor is installed 22 feet above the rails, giving 3½ to 6 feet clearance over a man standing on the top of a car. The overhead construction is calculated to be safe under all conditions and was so designed that the stress produced by a sheath of ice one-half inch in thickness, completely surrounding the cables, would only be one-sixth of the ultimate stress. Stresses due to wind have been figured on a basis of $16\frac{2}{3}$ pounds per square foot projected surface for cables and 25 pounds per square foot normal surface for flat surfaces; allowance being made for double wind-pressures in the summer, when the wind-storms are most severe. The intermediate bridges weigh 13,000 pounds each. These bridges are provided with square posts at the ends. Every two miles there are provided anchor-bridges which are of a heavier construction, have a more solid foundation, and are provided with A-shaped end posts. The anchor-bridges weigh 23,000 pounds each. The ends of the bridges carry cross-arms for transmission and power-circuits. No feeder is necessary for the entire length of the circuit, the conductor over a track being, for all practical purposes, connected in series from one end to the other. Two auxiliary feeders, however, are carried the entire length of the track to feed the current around any isolated section. These are carried on opposite sides of the bridges and are connected into the line at alternate anchor-bridges. The anchor-bridges are arranged, as far as possible to come at the end of blocks, the signal-semaphores being carried on the anchor-bridge structure. The signal-towers at the ends of anchor-bridges are utilized to afford attendance upon the apparatus carried upon the anchor-bridges. Section-insulators are inserted into the working conductors at each anchor-bridge and the conductors are connected to each other, to the feeders, and to the other parallel conductors through buses carried on the anchor-bridge, passing through a circuit-breaker first. By tripping the breaker at the ends any section of track may have the current cut off from it. The messengers at strain-bridges are interrupted, the ends being fastened to heavy strain insulators. The entire conductor over one section of track, from one end to the other, is connected in series and all the conductors in a section are in parallel when all conductors are connected up. The strain-bridges carry circuit-breakers, lightning-arresters, and shunt-transformers for supplying the operating current for circuit-breakers and the signals. The auxiliary feeders connect into the buses at alternate bridges so that in case one section becomes disabled the other section can feed around it. Two power-feeders are carried on the bridges for working three-phase apparatus along the line, and provision is also made for a three-phase circuit on top of each post at the ends of the anchor-bridge, as later on power may be supplied to the local street railways owned by the New Haven Company in this territory.

The line, of course, is entirely without sub-stations. When a circuit-breaker goes out on a bridge, it rings a bell and lights a lamp in a signal tower. The operator in the tower then puts it back into place by means of a switch which delivers current to an electric motor operating the breaker. The track is used as a return. At present the rails are bonded partly with outside bonds and partly with concealed bonds. Eventually all bonding will be concealed. A bond having a carrying capacity equal to the rail capacity is installed. Inductance bonds are installed at the end of every block and high-frequency low-voltage current is used to operate the signals. No underground or submarine crossings for conductors are employed. Where bridges over rivers occur, the wires are carried on towers sufficiently high to bring them clear of the masts of shipping, the train ordinarily floating across the gap, although a third rail carrying alternating current is installed in the short gap across the bridge, to which current can be turned on in case a train stalls on the bridge.

Experience has proved that there is no necessity of providing for the isolation of conductors into two-mile sections, but that four miles would have been ample, and it is probable, should the New Haven extend its electrification, that succeeding installations would have breakers and similar apparatus installed every four miles instead of two. With the high voltage employed, (11,000 volts) there is no such thing possible as the circuit-breakers failing to operate in case of a short circuit. The current rises so quickly that the circuit-breakers pop out instantaneously. With so much dead iron overhead and around the system, there is little trouble from lightning; the desirability of lightning-arresters in the power-house, is even seriously questioned.

Switch and storage yards are electrified at New Rochelle, Port Chester, and Stamford. At Port Chester a very ingenious and remarkably simple single-suspension system has been adopted. Posts are set up in pairs along the track, a catenary messenger cable spans the tracks between these posts from which hangers depend and rigidly suspend a straight cross-wire. These cross-wires in turn carry longitudinal catenary messengers from which are suspended the working conductors. The two posts and cross-wires thus take the place of an expensive bridge. The system is rigid, simple, and cheap. Six tracks may be spanned by each pair of poles. Where there are more than six tracks, it is preferable to erect intermediate poles between the outside poles. However, only the outside poles need be guyed, the cross-wires giving the intermediate poles sufficient stability. The cost of construction is about one-half that of the regular construction and the erection, renewal, and up-keep about one-half. The use of this system is contemplated in yard construction and on secondary track. It may be used later on the main line if it is found desirable, but it is thought that it is somewhat light for use on tracks where high speeds are maintained.

A marked improvement has also been made in the suspension of the line conductor. As originally installed, a succession of hard points where the conductor was gripped by the hangers were presented to the passage of the collector-shoe on the locomotive. The upward pressure of the locomotive shoe put kinks into the working conductor on each side of the hangers and these led to serious arcing on the collector. In the new construction, a cheap steel wire as a working conductor is suspended underneath the carrying conductor attached to it by means of clips at points intermediate between the hangers. The result is a perfectly straight, flexible, wire which cannot kink. As the collector-shoe passes along it between hangers, the working conductor springs at its middle, and when the shoe comes under a clip, the carrying conductor affords the necessary spring. At the time of our visit, two tracks had been equipped with the new construction and two tracks with the old. We stood at the side of the line and noted the passage of a number of trains. There was considerable arcing with the old construction, while there was hardly a flash with the new. We should say that the operation of this new construction, so far as sparking is concerned, was perfect. The adoption of this construction will go a long way toward insuring permanency of the aerial system. The working conductor, because of its meeting the situation so perfectly, will be very durable. In addition, it can be very easily and cheaply replaced as it is made of cheap iron wire to begin with, and to replace it, it is merely necessary to take off the clips and stick a new wire on in place of the old. In case a portion of it is torn down, it may be even left off for a while, the locomotive running on the conductor originally installed.

Haulage is done by means of electrical locomotives. The locomotives under contract requirements, were to handle 200-ton trains with stops every 2.2 miles and run at a schedule speed of 26 miles per hour, this giving a maximum speed of 45 miles per hour. It was also provided that the locomotives should haul this train from 60 to 70 miles per hour on long runs, and a 250-ton train at 60 miles per hour. As a matter of fact, on tests, the locomotives successfully handled 300-ton trains on

200-ton requirements. The bulk of the New Haven trains are of moderate weight and, consequently, a locomotive of smaller capacity than the New York Central's locomotives was chosen; a machine of the capacity to give maximum efficiency for hauling the ordinary New Haven train being purchased. The heavy trains are hauled by two locomotives double-headed. On long runs the New Haven locomotive, it is claimed, will haul fully as heavy trains as the New York Central locomotives, the long-run capacity of the New York Central locomotives being limited by heating of the resistances. The locomotives are fitted to operate both on high-tension alternating current and on the direct current supplied by the third rail over the New York Central terminal electrification, as the locomotives have to haul the New Haven trains out of the Grand Central terminal to Woodlawn, over the New York Central tracks. They are said by New Haven officials to make less speed than the New York Central locomotives within the New York Central zone, but to make a higher speed when operating on their own system. The writer observed that on leaving the New York Central zone and getting on the alternating-current section, the locomotive was able to make very high speeds.

The New Haven locomotives are equipped each with four single-phase motors carried by a quill suspension from the driving wheels. The motors are cooled by an air-blast supplied from a small motor-driven fan, this serving not only to keep the motor cool, but to prevent the entrance of dirt and other foreign matter tending to cause motor troubles which are liable to run up maintenance charges. Current is collected from overhead by a shoe carried on a pantagraph kept in contact by springs tending to push the shoe upwards and pulled down out of contact by means of an air cylinder. The upward pressure on the shoe is about 12 pounds, and the pantagraph has a range of 8½ feet. Shoes carried on the trucks are employed for collecting the third-rail current within the New York Central zone and an overhead pantagraph collector similar to those on the New York Central locomotives is also provided for taking current from overhead when necessary in the New York Central zone. The high-voltage current is carried through a transformer inside the locomotive, where the voltage is transformed to the working voltage for the motor. The transformer is provided with several outlet taps so that current at different voltages can be taken from it, thus affording a voltage control over the motor. A double-end multiple control is provided for the locomotive. For operation within the terminal zone a complete set of direct-current control apparatus is provided with necessary resistances for the motor. There is a good deal of duplication in the locomotive equipment, leading to objectionable complication for a machine in ordinary operating hands. Some of the complication is due to a desire to provide against every possible interruption of traffic, even the air-compressors and motor ventilator fans being installed in duplicate, but the greater part of it arises from the necessity of providing suitable apparatus for operating over the direct-current zone of the New York Central, and in straight single-phase equipment could of course be eliminated. The locomotive is provided with means for pneumatically lowering or raising the third-rail contact-shoes, lowering or raising the pantagraphs, ringing the bell, and blowing the whistle,— these operations being effected by the pressing down of small knobs on top of the control-box.

At present the locomotives carry an operator, a lookout, and an instructor. The instructor will be taken off shortly. Whether two men or one will be carried on each locomotive is a question for decision after sufficient operating experience has been gained. The operator regulates the speed of the locomotive by a chart that is just above the control, giving the number of amperes corresponding to the given speeds on each notch of the controller. Some difficulty has been experienced from keeping the operators from taking curves at too high speeds. High speeds are so easily attained that the operatives have a tendency to regard the locomotive as a plaything. The maintenance on these locomotives has been pulled down to 3 cents per locomotive mile against about 8 cents for steam locomotives on this road. The locomotives accelerate at about .45 miles per hour per second.

The New Haven have recently purchased several motor cars for use on their branch lines. These motor cars are equipped with 320-horsepower motors, have double-end control, and the apparatus with which they are equipped is very similar to the locomotive apparatus, except that no provision is made for direct-current working. These motor cars are designed to haul one or two standard passenger coaches as trailers, and are designed to have an acceleration of 1.6 miles per hour per second.

The preliminary estimate for the cost of the electrification of the New Haven, was given out as follows:

Power-house, including real estate.........	$1,130,000
Overhead construction, 21.45 miles route, four-track	570,000
35 Locomotives..........................	1,050,000
	$2,750,000

The estimated saving per annum by electrical operation, is as follows:

Service	Ton Miles per Annum	Tons Coal Steam	Tons Coal Electric
Express..........	592,242	57,477	29,870
Local Express Service..........	348,000	58,300	28,600
Freight Service....	2,223,000,000	187,844	139,010

Service	Cost Coal Steam	Cost Coal Electric	Saving in Coal
Express..........	$183,830	$89,620	$94,210
Local Express Service..........	186,560	85,800	100,760
Freight Service....	563,530	417,030	146,500
		Total saving	$341,476

Electric service into Grand Central Station from New Rochelle was begun July 5, 1907, with five trains a day each way, and complete electrical passenger service between Stamford and New York was put on in June, 1908. It was just about this time that we visited this road and, except for minor matters, found the system working well. We went over the entire length of the line and, through the kindness of the New Haven officials, were enabled to ride on the locomotives on each kind of run. To our personal observation, the locomotives were readily handled and easily operated. The motor commutators showed very little sparking on the locomotives on which we were. While certain of their trains were double-headed, we rode on one of their heaviest and fastest trains to which a single locomotive was attached, and with which schedule was maintained without difficulty.

The New Haven is not handling its freight, as yet, by electricity, although electrical freight-handling is ultimately contemplated, and the presence of steam locomotives on the line in connection with the electrical locomotives is regarded as inimical to the upkeep of the line-construction.

It is generally understood around New York, that the New Haven may arrange to connect by Long Island City, or by a subway down the eastern side of Manhattan Island, with the Pennsylvania system, and run its trains into the new Pennsylvania terminal now under construction. Should this be the case, the New Haven freight would probably go into Long Island City, and it seems reasonable to expect that the freight will then be handled by electricity. That the New Haven has planned for the electrical handling of its freight, we have been assured from reliable sources. In addition, the public estimates of savings on the New Haven, take into consideration the saving to be gained by the electrical handling of freight.

In 1904, Mr. C. S. Mellen, president of the New Haven railroad, was quoted in an interview: "Looking ahead a very few years on such portions of systems as have eliminated these dangerous crossings, as, for instance, our line between New York and New Haven, I confidently expect to see the steam locomotive become in the nature of a curiosity."

Mr. E. H. McHenry, vice-president of this railroad, discussed the handling of freight by electricity, in an article published in the Street Railway Journal of August 17, 1907. We quote his article extensively in the section on freight-handling. In this article, his statement, "to secure the fullest economy, it is necessary at least to extend the new service over the whole length of the existing engine stage or district and to include both passenger and freight trains," is significant.

The New Haven has adopted a comprehensive plan of securing street-railway and interurban connections with its line so that these roads may be used as feeders to the larger system, and also that existent gaps in transportation routes afforded by the one system or the other can be filled in. Mr. C. S. Mellen, the president of this railroad, in his analyses of passenger-transportation problems, given to the press from time to time, has probably treated the subject more broadly, and with a larger eye to the future, than any other public official. He has proposed to electrify steam lines between towns to afford interurban service, and to connect these lines within towns with the local street-railway systems, so that the passenger may be delivered at his house-door. In apparent pursuance of this policy, in 1906, the New Haven obtained the right to add two tracks to its line and to run an interurban line on them from New Rochelle to Larchmont; and in 1907, their lines from Middletown to Berlin and to Meriden were converted to electric lines, and arrangements made to connect these lines at their terminals with the local street-railway lines; the lines forming practically a part of the system of the Consolidated Railway and Light Company, a New Haven property. These are single-track lines, the Middletown-Berlin section being 9.53 miles long and the Westfield-Meriden section 7.21 miles long. The line-equipment is partly single-pole-bracket construction and partly a double-pole-span construction. 600-volt direct current is used, a No. 0000 trolley wire being installed with a feeder connected into the trolley every 1,000 feet. In addition to being bonded, the track rails are connected to a return feeder every 1,200 feet.

Another of their branch steam lines, connecting Hartford, Vernon, and Melrose, has been converted to an electric interurban road. This electrification was carried out in 1907. The route begins at Hartford, Conn., follows the tracks of the Hartford Street Railway 2½ miles to East Burnside, where it is deflected to the steam-road right of way, connecting Hartford, Manchester, and Willimantic, and forming a part of the New Haven railroad's "Poughkeepsie Bridge to Boston" line. From East Burnside the electrification is carried out on the double track of the steam road through Buckland, Manchester, and Talcottville to Vernon Junction (10 miles), where the line swings north and passes to Rockville and Melrose over a single-track branch formerly operated by steam, 13 miles long. Direct-current equipment is used at 600 volts. Power is secured from the Hartford Street Railway Company's plant and carried to the sub-stations by an 11,000-volt three-phase transmission line. The line is equipped with a single-catenary construction with 3-point suspension, a ⅜-inch messenger being used and 150-foot spans employed. The track is bonded with No. 0000 cable bonds and cross-bonded every 2000 feet.

Since the electrification of the New Haven's main line between Stamford and Woodlawn, the old electrified New Canaan branch from Stamford to New Canaan has been changed from a direct-current trolley line to an 11,000-volt single-phase line, to conform to the standard used on the main line. It is predicted that the New Haven railroad from New York to Boston will eventually be operated entirely by electricity. According to the Street Railway Journal, May 16, 1908, it is semi-officially asserted that the Stamford-New Haven lines would be electrified next. It is stated that Mr. Mellen said in March, 1906, that the New Haven would be electrified from Boston to Providence, after four-tracking and eliminating grade-crossings, if expectations should be met on the western end of the line. Mr. T. E. Byrnes, vice-president of the New York, New Haven & Hartford railroad, in an interview printed in the Boston Herald, July 3, 1908, is quoted:

"We shall electrify our roads, every one of them, just as soon as we are satisfied that our system of electrification is what it should be. Of course, this is a big undertaking and will take a great deal of time. In the first place, all grade-crossings will have to be abolished, a work, by the way, which has already been in progress some time. The suburban lines, especially at points where the communities are large, will be first equipped, and the electrification will be carried out from section to section *until we have substituted electricity for steam throughout our entire* *system from Boston to New York.* We feel that the experimental stage of our electrical railroad is practically past and *that our system has been demonstrated to be successful.*"

On Wednesday, April 8, 1906, speaking before the Boston Fruit and Produce Exchange, Mr. Byrnes stated that the New Haven's suburban lines within a 20-mile radius of Boston would be electrified within five or six years, if his company was allowed to control the Boston and Maine. He is quoted as follows:

"If this thing is allowed to go through, your suburban territory will be electrified and you will be able to come into Boston and pass from one depot to another by means of a tunnel. *It has been said that our electrical experiments in New York have not been a success. They have been a success and we are going to adopt the same system on the suburban service here just as fast as it can be done.*"

LONG ISLAND RAILROAD

The railroad is controlled by Pennsylvania interests and will eventually be an adjunct of the Pennsylvania terminal system into New York. At the time of its equipment it was the largest electrification in the United States. The railroad runs from Brooklyn, east through the middle of Long Island to Montauk Point, with numerous north and south branches to the seaside resorts and suburban towns. Only the western end of the system is electrified. The main terminus of the road is in Long Island City opposite thirty-fourth Street in the Borough of Manhattan, from which terminus only steam trains are despatched, although the power-house for the electrical working of this system is located at this point. The road has another important terminus at Atlantic and Flatbush Avenues in Brooklyn, from which a large suburban passenger traffic is derived. The road has a direct connection with the Brooklyn Rapid Transit Company's elevated railroad and hauls certain of that company's trains from Rockaway Beach. The Atlantic Avenue terminal is also connected with the recently opened extension of the New York Subway to Brooklyn and it is probable that a through service will be instituted by the Long Island railroad and the Interborough Rapid Transit Company. The Long Island railroad's line originally ran through a farming section, but the growth of Brooklyn and Long Island City and the movement of population of Greater New York toward the suburbs, have turned the country traversed by the road into a succession of suburban towns. In addition, the road served three popular race-tracks and reached Rockaway Beach, besides going to a number of desirable residence towns such as Hempstead, Babylon, Oyster Bay, etc. Owing to a desire to abolish grade-crossings within the city, the city of Brooklyn secured an agreement from the Long Island railroad on May 18, 1897, by which the road undertook to remove its tracks along Atlantic Avenue from the surface and to operate its passenger trains by a motor power not requiring combustion. This practically required the electrification of the Atlantic Avenue line, which was a double-track line extending from Flatbush Avenue along Atlantic Avenue to East New York. From thence it was four-tracked to Jamaica. The electrified section of the road at present passes through a tunnel under Atlantic Avenue, thence by an elevated structure to the limits of the Borough of Brooklyn, and the remaining distance on the surface,—passing through numerous towns along its route with crossings at grade. At Woodhaven Junction, one line goes south to Rockaway Beach, while another line continues east and divides again into lines extending to Hempstead and to Valley Stream. The line required to be electrified only extended to the limits of the city of Brooklyn, but the road adopted the plan of electrifying to out-lying towns, believing that the better service offered would attract a sufficiently increased traffic to give a net profit on the investment. The initial electrification extended as follows:

Atlantic Avenue Line:	
Flatbush Avenue to Jamaica and thence to Belmont Park	14.12 miles
Rockaway Division:	
From Woodhaven Junction to Rockaway Park .	8.53 miles
Jamaica to Metropolitan race track............	2.6 "
A total of 86 miles equivalent single trackage.	

The daily passenger-train service in and out of Long Island City, at the time the electrification was determined upon, consisted of 425 trains of 2,500 cars; and at Flatbush Avenue, 266 trains comprising 550 cars. It was estimated that there would be affected by the electrification 300 trains hauling 1,320 cars and the maximum train movement contemplated one way in one hour was 20 trains carrying 135 cars. For this, a power-station equipment of 16,500 kilowatts was installed. The through traffic to Montauk Point was left to be hauled by steam out of the Long Island terminal and the local traffic over the network of lines passing through suburban towns was designed to be handled by electricity. There is still a considerable steam service maintained to these towns. The business which it was primarily intended to handle by electricity, was composed of the suburban trains doing a heavy local business to Jamaica and other points and a very heavy excursion business to Rockaway Beach and the race-tracks. This last business is responsible for a very fluctuating loading at different seasons of the year and on different days during a particular season, and the conditions are somewhat unfavorable to electrical working because it produces a low-load factor upon the electrical equipment. Nevertheless, it has been deemed advisable to handle it largely by electricity, although it is expected that the growth of the suburban towns to come later will serve to equalize the traffic, and that the connections with the Pennsylvania electrification will also serve to steady the load. At present, extreme fluctuations are taken care of partly by a storage-battery installation at one plant and by portable sub-stations which may be connected to the sections subject to an unusually heavy traffic. Extensive additional electrification is being continually carried on, and this will also help to steady it. When the Pennsylvania tunnels, into New York City and across to Long Island, are completed, the power house of the Long Island railroad will be increased to four or five times its present capacity and will carry the load of the Pennsylvania terminal in addition to the Long Island load, when the Long Island load will form a small part of the total station load, and even very large fluctuations on the Long Island will cause little disturbance of the total power-house load.

The system originally installed on the Long Island was designed to afford a service of 15 six-car trains per hour each way, from Flatbush Avenue to Belmont Park; 3 six-car trains per hour each way, from Flatbush Avenue to Rockaway Park; and 2 four-car trains per hour each way, from Valley Stream to Hammel (the Valley Stream-Hammel line being a line running in an eastern direction from a station just short of Rockaway Park to Valley Stream, 8 miles distant).

The cars were adapted to be used over the Brooklyn Rapid Transit line or over the Interborough system (subway), a 600-volt direct current being supplied by a third rail. Power is generated in a power-station at Long Island City, containing three 5,500-kilowatt Westinghouse-Parsons turbines, generating three-phase current at 11,000 volts. Upon the completion of the Pennsylvania tunnels, the station will ultimately contain six units and an addition will be built to give a total capacity of thirteen 5,500-kilowatt units. Babcock and Wilcox boilers are employed, arranged on two floors, fed by automatic stokers. A direct-current turbine exciter set and a motor-generator exciter set supply the exciting current. A small storage battery is installed in the main power-station to furnish the exciting current in case of breakdown. The power-station is off the electrical center of gravity of the system and is not even located on the electrified section of the line, the location being made to be convenient, later, for the Pennsylvania electrification. All of the station current is carried out over five lines to a sub-station at Woodhaven Junction, near the center of the network, where it is distributed to the system. The current is carried over to the railroad yard in conduits, whence it passes to an overhead line running along the steam railroad tracks to Winfield, from which place it goes across country to Glendale on a special right of way and from Glendale Junction it follows the railroad tracks to Woodhaven, where it enters the sub-station to be distributed. All overhead currents are carried by bare wires, lightning-arresters being installed in each sub-station and in specially erected arrester and cut-out houses at all points where wires pass from overhead to underground, or vice versa. The high-tension transmission lines from Woodhaven Junction to the other sub-stations, in general, are overhead lines carried on steel poles. Where stretches of water are encountered (line to Rockaway Beach) the transmission line is carried as an armored submarine cable laid in a trench in the bottom of the harbor, excavated by a water jet Along the tunnel sections of the line the transmission cables are carried in vitrified-tile ducts laid in cement in the walls of the tunnel or along the right of way at the edge of the track. Sub-stations are located as follows:

1. Grand and Atlantic Avenues, Brooklyn.
2. East New York.
3. Woodhaven Junction.
4. Near Rockaway Junction.
5. Hammel.

Woodhaven Junction is the largest of these sub-stations, containing at present three 1,500-kilowatt rotary converters and nine 550-kilowatt stationary transformers. Ultimately it will have six 1,500-kilowatt rotaries with the necessary complement of stationary transformers. The station at Grand Avenue contains three 1,000-kilowatt rotaries (ultimately four 1,500-kilowatt rotaries), and nine 375-kilowatt static transformers. Rockaway Junction contains two 1,000-kilowatt rotaries, (ultimately three 1,500-kilowatt rotaries), and six 375-kilowatt static transformers. East New York contains three 1,000-kilowatt rotaries (ultimately four 1,500-kilowatt rotaries), and nine 375-kilowatt static transformers. Hammel contains two 1,000-kilowatt rotaries (ultimately six 1,500-kilowatt rotaries), and six 375-kilowatt static transformers.

The Hammel sub-station is also supplied with a storage battery with a rating of 2,000-kilowatt hours, having been the largest storage battery in the world at the time of its installation. This battery was installed because the load on the Hammel station is more variable than on the other stations, and because the Hammel station is most liable to interruption. It is situated on a peninsula just a little distance short of Rockaway Park and the transmission line makes two long crossings under water to reach it. In the winter time the load on the Hammel station is light and it is possible to shut down the rotaries for a good deal of the time and operate on the battery. During the summer months the Hammel station is subjected to very severe peak loads which the battery carries.

The sub-stations are located at junction points where the concentration of load comes. They are substantial brick and steel buildings of fire-proof construction and, with the exception of the Woodlawn and Hammel stations, are all very much alike in general arrangement. The rotaries and transformers are installed on the first floor, while the switch-boards are carried in two galleries, the main board being on one side and the high-tension on the other side of the building. The cellar contains a plenum chamber for carrying the air-blast to the transformers. The foundations for the rotary converters in the sub-stations are all made large enough to hold 1,500 kilowatt rotaries. As the traffic develops, the 1,000-kilowatt rotaries will be removed from the sub-stations in which they are installed and put in new stations on later electrifications, 1,500-kilowatt rotaries taking their places. In addition to the fixed sub-stations, the road is provided with portable sub-stations. These are steel cars which contain, each, one 1,000-kilowatt rotary and three 375-kilowatt static transformers, together with switch-board and control apparatus. The regular sub-stations have tracks in them and connections so that in case a heavy load is anticipated on one of the sub-stations, a portable sub-station can be set in on the tracks and connected up to the fixed sub-station. This was the method of handling the situation when the race-track crowds taxed the road capacity. It was customary to connect up one of these sub-stations to suitable connections near Belmont Park. During our visit to this railroad last summer, we found one of these sub-stations in use for extension purposes, the Long Island railroad having just completed its electrification into Hempstead; the portable sub-station being employed until the regular one should be installed.

The current is converted at the sub-stations into 600-volt current and led directly into the third rail. In general, no feeders are employed, the third rails giving sufficient carrying capacity from station to station. At points where there is complicated track work, resulting in a number of short sections of third rail, switch-houses have been installed and a feeder led from the station to this switch-house and the current led to it from the various isolated sections of rail by short sections of cable. This arrangement is being done away with now and these small sections tied right into the third-rail line. Circuit-breaker houses were originally installed every two miles, the rail being interrupted and the connection between adjoining ends made through circuit-breakers. It has been found that four miles is sufficiently close for these circuit-breaker houses and this spacing is adopted for the later construction. The third rail is 27 inches from the gauge line and 3½ inches above the top of the track rail and is carried upon vitrified-clay insulators supported at the ends of long ties. A wooden sheathing protects the rail throughout its entire length. This is composed of a 2-inch plank held four inches above the rail by brackets which are carried on wooden uprights outside the rail and attached to it by steel brackets. At station platforms an extra side-sheathing is added and a dummy sheathing is carried at the side of the track, at which there is no rail, to protect passengers at the stations from coming in contact with the collector shoes. The third rail is a 100-pound rail in 33-foot lengths, to correspond with the track rail and be interchangeable with it. Some 60-pound rail is used. The rails are bonded with four solid bonds having a carrying capacity of 1,650,000 cir. mil. The third rail is interrupted at station platforms and at highway crossings, the current being carried across by jumpers which are now installed in tile conduits, but were formerly simply buried in the ground. The jumpers are of 500,000, 1,000,000, or 2,000,000 lead-covered cables, as may be required. Each jumper-cable end has a copper lug sweated on it with four 400,000-circular-mil. copper cables attached (in the case of the 1,000,000-circular-mil. jumpers), the terminals of these cables being expanded into holes drilled in the end of the rail. The track is bonded to serve as a return with the usual provision of impedance bonds at the ends of blocks, and is cross-bonded through impedance bonds every 1,500 feet. Past draw-bridges, submarine cables are installed between the ends of the track rails for the return circuit.

The trains on this road are composed of motor cars and trailers, in the ratio of three motor cars to two trailers, and trains vary in length from six to twelve cars. The original equipment comprised 130 motor cars, the cars being built of steel and similar to those used in the New York subway, each car weighing 83,000 pounds. Each motor car is equipped with two 200-horse-power motors, both being geared to the same truck. The cars are capable of a maximum speed of 55 miles per hour and of maintaining the schedule with stops 1.6 miles apart, of 25 miles an hour.

The electrification originally contemplated was to cover 86 miles of equivalent single-track mileage, but a total equivalent mileage of 97½ miles was actually electrically equipped at first — over 42 miles of main-line track comprising 90 miles of equivalent single-track mileage and 7½ miles of sidings. This has since been considerably extended. The road has recently been granted the right to build a cut-off near Long Island City which will bring about the elimination of all grade-crossings from Jamaica to Woodside and the electrification of the line between these points. The next line on the company program is that from Whitestone Landing to Port Washington.

Work on the electrification of the Long Island railroad was begun in 1903, the ground for the power-house being broken on September 15, of that year. The work on the sub-stations was begun the following summer, and on the transmission and third-rail system in the fall of 1904. The entire work was completed in the summer of 1905, the electric service being put into operation on June 26, 1905.

In addition to its electrified section, the Long Island road supplies current to the Glen Cove railway,— a street-railway system from Glen Cove, five miles in length. This road was originally a direct-current road, power being purchased locally, but it was changed into a single-phase system because of the Long Island railroad being able to supply current to them (transmitted a distance of 27 miles) cheaper than the small local power-house could sell it.

The operation of the railroad has been very successful, there having been little trouble with the electrical apparatus. The running time from Flatbush Avenue to Rockaway Park is five minutes less than under steam operation. The electrification has brought about a reduction in the working expenses, but not enough as yet to pay the carrying charges on the investment,— owing to a good deal of the installation being to care for larger future demands. The freight traffic and passenger traffic originating at Long Island City, together with all through traffic, is handled by steam. For a while two electrical locomotives belonging to the Pennsylvania system were operated on the line on freight-switching, as an experiment, but they were afterward sent to the

West Jersey & Seashore railroad, another electrified road controlled by the Pennsylvania system. The annual report of 1907 states:

"Its workings during the year have been very successful and the service has been reliable and efficient in every respect, and, while it has not yet been economical owing to the fact that your power is not fully employed, it has materially increased your passenger traffic."

In addition, the report refers to the plans for the electrification from Long Island City to Port Washington and to Whitestone Landing; and to a plan, as soon as the East River tunnels are completed, of electrifying from Long Island City to Jamaica and Woodhaven Junction by way of the Glendale cut-off, a connection between the main line, the Montauk division, and the Rockaway Beach division.

WEST JERSEY & SEASHORE RAILROAD

This road is controlled by the Pennsylvania interests. It runs from Camden, N. J., just across from Philadelphia, to Atlantic City,— a distance of about 65 miles. The Pennsylvania controls two lines carrying local traffic between Philadelphia and Atlantic City, of which this was the most severely taxed. It was electrified in order to get a greater train movement over the line and for reasons of economy. It is possible, also, that the line may have been electrified to partly shut off interurban competition, for when the charter was granted to the Delaware River & Atlantic City Railway Company, it was announced that a four-track electric road would be built from Philadelphia to Atlantic City, although the line was not so constructed. It is the first example of the electrification of an express service on a through line, aside from terminal considerations, in the United States.

The work was carried out in a very short time, the General Electric Company being given the contract for the equipment in November, 1905, and scheduled electric service begun on the road October 18, 1906. The electrified line comprises about 150 miles of single track. The road is double-tracked over the line from Camden, by way of Newfield, to Atlantic City (65 miles,) three-tracked from Camden to Woodbury and single-track from Newfield to Millville (10 miles). To provide for the electrification, the track was largely rebuilt, a new signal system was installed, and new fences, cattle guards, culverts, and bridges in general installed. Some new telegraph and telephone equipment was provided and a number of station changes made, new terminal stations being built at both ends. The entire work involved an expenditure of between $2,000,000 and $3,000,000.

The line is of a standard 600-volt direct-current third-rail construction from Camden to Atlantic City, except for 4.4 miles from Haddon Avenue to South Gloucester, where the track passes through city streets at grade and an overhead trolley is used. An overhead trolley is installed on the branch from Newfield to Millville. In addition, the Atlantic City & Seashore railway uses the West Jersey & Seashore tracks for four miles of its route. This is a local street-railway system starting at the Board Walk in Atlantic City, connecting with the West Jersey & Seashore tracks, running four miles west on this track and then branching out to Somers Point. It takes its current from an overhead trolley, except on the West Jersey & Seashore section, where current is taken from the third rail.

The power-house contains turbo-generators of 6,000-kilowatt combined capacity, current being generated at 6,600 volts at the power-house and stepped up to 33,000 volts, at which voltage it is delivered to the transmission lines. At the sub-stations this is converted into 650-volt direct-current for supplying the third rail. The transmission line is in duplicate, chestnut poles being set up 125 feet apart, carrying six No. 1 B. & S. gauge bare copper wires for the transmission lines, a 7-strand steel cable $\frac{5}{16}$-inch in diameter being strung over the top of the wires for lightning protection. This transmission line was erected at the rate of 2 miles a day. The third rail is a 100-pound rail, so chosen that it might be interchangeable with the track rail. It has a conductivity equivalent to 1,200,000-cir.-mil. copper. It is protected only at stations, it is without feeders, and is sectionalized midway between sub-stations, the east and west bound third rails being inter-connected at their ends, and midway between stations, no feeders being installed. The trolley section of the road is double-track span construction; poles placed 100 feet apart; trolley wire being No. 0000 copper and the span wire being $\frac{3}{8}$-inch galvanized steel. Two 750,000-cir.-mil. feeders are supplied for the trolley section. Lightning-arresters are placed on poles at every 1,000 feet on the trolley section. The track is bonded in the usual manner to serve as a return circuit. Inductance bonds have a resistance per block equal to 40 feet of third rail.

Multiple-unit trains are used on the road, the motor cars each being equipped with 200-horse-power motors. The service contemplated was to put on a 3-car train every 15 minutes between Camden and Atlantic City, this train to make 64 miles in 80 minutes without stops. In addition, a 2-car half-hourly schedule was planned for locals and a 10-minute 2-car service between Camden and Woodbury ($8\frac{1}{2}$ miles). Full service calls for 58 cars in operation on the line at a time, and at present 54 trains per day each way are run, instead of 25 with steam. The traffic is increasing and an additional equipment is contemplated. A report, recently made public, shows that for the first year of operation, there has been an increase of through traffic, and an increase in strictly local traffic of 19.54% against 1.85% for the preceding year.

PENNSYLVANIA RAILROAD

The Long Island railroad and the West Jersey & Seashore railroad just described, are controlled by Pennsylvania interests. The initial venture of the Pennsylvania into electrical traction was in 1895, when the Board of Directors authorized an installation of electric traction on the Bordentown & Mt. Holly branch of the Amboy division. This was completed in July 1895, and comprised 7.66 miles of double-track line from Bordentown to Mt. Holly, an overhead-trolley direct-current installation being provided. A motor car equipped with two 75-horse-power motors hauled a standard coach over the line.

The Pennsylvania is at present engaged in the building of a terminal into New York City, which is one of the largest engineering projects of the present day. A double-track tunnel will pass under the Hudson River into their terminal in the heart of Manhattan Island and the tracks then carried under the East River through a double-track tunnel to Long Island City, where connection will be made to the Long Island railroad, and on the outskirts of which a large storage and terminal yard will be built. It will be necessary to operate the trains hauled into this tunnel by electricity, and the present power-house installation of the Long Island railroad will serve as a nucleus for the power-house equipment required for this electrification. When this is completed, it will be one of the most important electrifications in the world.

The Pennsylvania is at present experimenting to determine the system which they shall install. For these experiments they have had built three electric locomotives, one of which is a geared locomotive to operate on direct current; the second is a gearless direct-current locomotive which is equipped with four 350-horse-power motors and weighs about 100 tons. The third is an alternating-current, gearless, single-phase locomotive similar to those used on the New York, New Haven & Hartford railroad. The complete single-phase locomotive is composed of two duplicate halves coupled together, and has a total weight of 145 tons. Each section is equipped with four 500-horse-power motors, there being 4,000 horse-power comprised in the whole unit. It is intended to use a voltage of 300 volts at the motor commutators. The locomotive is designed with the idea of getting speed on the 2% grade in the tunnel. It has made 73 miles per hour on a test-track at Pittsburgh and is capable of making 90 miles per hour on a straight track. 24,000-pounds draw-bar pull has been developed with one section. At present, 5 miles of the Long Island railroad, east of Garden City, is being equipped with single-phase equipment by the Pennsylvania for experimental work with this locomotive.

WEST SHORE RAILROAD

The West Shore is one of the New York Central lines used largely for freight, and is controlled by the Vanderbilt interests. Several years ago the Vanderbilt capital began to be interested in trolley roads in Central and Western New York, it being generally understood that the money was being put into these roads partly as an investment, partly to secure them as feeders for the Vanderbilt roads, and largely to insure their operation being friendly to the Vanderbilt roads. In 1905, a double-track section of the West Shore, 3.17 miles long, between Frankfort and Herkimer, N. Y., was equipped for electrical working to supply a link in the Utica & Mohawk Valley system and used in joint operation by steam cars of the West Shore and electric cars of the Utica & Mohawk Valley, the link filling a gap in the Vanderbilt trolley roads and giving them a chain of trolleys from Rochester to Little Falls, a distance of 160 miles. This link has rather a curious history.

Before the Utica & Mohawk Valley got into the field, the electrical service in this section was afforded by the Herkimer, Mohawk, Ilion & Frankfort Electric Railway Company, a single-track line built in the highways. The Utica & Mohawk Valley purchased it and began to reconstruct the line as a double-track line on a private right of way, in order to establish a high-speed interurban service. The villages of Ilion and Mohawk refused to give them the right to double-track their road except under onerous conditions. Meanwhile, the Utica & Mohawk Valley opened negotiations with the West Shore which were satisfactorily consummated, the result being the electrification of that line between Herkimer and Frankfort and the running around the outskirts of Ilion and Mohawk, connecting tracks having been built between the Utica & Mohawk Valley and the West Shore to form a cut-off.

The equipment of this short electrified section was with a direct-current trolley wire, suspended from a single-catenary messenger. The trolley is of No. 0000 copper, the catenary of $\frac{9}{32}$-inch steel cable, covered.

The trolley is carried 24 feet above the top of the rail. The whole equipment cost somewhat under $75,000. This track is used in common by steam and electric trains and the electrical working was officially opened December 14, 1905.

The Utica & Mohawk Valley, the Oneida railway, and the West Shore made a further agreement whereby the latter agreed to relinquish all passenger traffic between Utica and Syracuse, reserving the right to haul freight over the road by steam. The New York Central with four tracks and the West Shore with two tracks are practically parallel between Albany and Buffalo. Consequently, the Vanderbilt interests have, in general, run the bulk of the passenger traffic over the New York Central tracks, putting a moderate number of passenger trains on the West Shore, but giving the road a large freight traffic. When the interurbans began to parallel the New York Central and competition from them grew strong, the latter's local traffic began to fall off. Consequently, the New York Central interests, after acquiring a number of electric roads, determined to fill in the gaps and offer the best interurban service in the section, as well as the best steam service, in order to preserve their monopoly of the traffic. This section between Utica and Syracuse formed the longest gap in the system, and a decision was made to electrify this section of the West Shore to fill the gap.

The Oneida company being the most convenient local Vanderbilt company to handle the matter, the electrification of the West Shore road was turned over to it and the work was actually carried out by the Oneida company. The distance from Syracuse to Utica is 43 miles. Owing to the different classes of trains it was proposed to run, namely, steam freight, and steam through passenger trains and the West Shore electrical locals and electrical express trains, it was necessary to add extra trackage to the existing double-track road, in order to provide for trains meeting and passing without delay. 8.8 miles of third track were added to allow the passage of trains and 4.6 miles of fourth track were added for the same purpose and for freight storage. Thus, the electrification extends over

30.515 miles two-track.
8.843 miles three-track.
4.582 miles four-track.

Total, 43.940 miles of route, and 105.887 miles electrified.

A third-rail 600-volt direct-current standard construction has been adopted. Power will be bought eventually from the Hudson River

Electric Power Company, and will be supplied from this company's hydraulic plant at 60,000 volts. Until the Hudson River company has its hydraulic plant completed, the power will be supplied from a temporary steam plant. There are four sub-stations located as follows:

1. Clark's Mills.
2. 1½ miles west of Vernon.
3. 1 mile west of Canastota.
4. Manlius Center.

Distance between sub-stations, 10¾ miles.

The transmission line is carried on steel towers, the conductors being No. 0000 stranded copper. The third rail is an under-running 70-pound steel rail of the New York Central type. It is, however, of ordinary steel and not specially low in carbon and manganese, as required by the larger electrifications. It has a conductivity equivalent to 1,023,000 cir. mils. of copper. In places the protective sheathing of the rail is composed of indurated fiber instead of wood. The rail is without feeders and there is no cross-connecting.

Two-car trains are run, two trains being run each way each hour. The trains leave the West Shore tracks in Utica and Syracuse and run over the local street-railway tracks.

The work was begun in 1906 and opened to traffic in the summer of 1907.

BALTIMORE & OHIO RAILROAD

In order to get rid of smoke and gases in tunnels encountered in its passage through Baltimore, the Baltimore & Ohio railroad, in 1895, electrified its section of track through Baltimore, the service being inaugurated in August of that year. The electrification extends from Camden Yard to Waverly, over 3.4 miles of double track. The distance includes 7 curves of from 5 degrees to 11 degrees and is on a grade of 1 to 1.5%. The route passes through 7 tunnels of from 400 to 9,000 feet in length. The longer tunnels are as follows:

1. 9,000 feet, 1 % grade.
2. 2,000 feet 1.4% grade.
3. 2,500 feet 1.5% grade.
4. 4,500 feet 0.8% grade.

There are between 300 and 400 trains a day through the tunnels, the passenger trains stopping usually at three stations along the route.

The electric locomotives are used on what is practically a "pusher" service. The steam engines are left on the head of the trains and the east-bound trains are pushed through the tunnel by the electric locomotives. The west-bound trains drift through the tunnel on the down grade,— the electric locomotive usually returning light, after pushing a train through the tunnel. Both passenger and freight trains are so handled, special low-speed, geared locomotives having recently been purchased for the freight service.

Current is supplied at 600 volts, direct current being used. Originally the current was supplied to the locomotive through an aerial conductor. This was formed of two Z-shaped rails supported by a bridgework and protected by a sheet-iron canopy. The current was collected by a shoe reaching through a slot between the webs of the Z's and sliding along the upper sides of the lower webs. This was subjected to severe corrosive action from the locomotive gases and became so badly run down that it was taken down and replaced by a third-rail along the outside of the track, it being estimated that the third-rail maintenance would be less than that of the overhead conductor. The third rail is protected in the tunnels by a plank set on edge on each side, the upper edge being slightly above the top of the rail. At the Union Station the train-platform flooring is carried over the third rail so as to leave only a slot about an inch in width above the top of the rail through which the web of the collector-shoe passes. At Mt. Royal Station, the rail is discontinued past the station; trains floating across the gap. A rather unusual feature is the installation of an electrified rail between two of the tracks at a bad cross-over, so arranged that it may be hoisted by a lever from the signal-tower to afford a contact with the collector-shoe of the locomotive in case the locomotive should get stuck at points on the cross-over, where the continuity of the third rail is interrupted. In this particular case it was cheaper to install the conductor in this way than to put it overhead and equip the locomotives with overhead collector-shoes; and as it very rarely happens that a locomotive stops in a position where it would be unable to collect the current from any of the other sections of the rail, the additional duty imposed upon the man in the signal-tower is very slight.

The power-house is an antiquated affair equipped with small units exhausting at atmospheric pressure. In addition, some of the engines are high-speed engines. The economy with such an equipment cannot be very good. Two storage batteries are in use, one at the power-plant and one at the Union Station. These storage batteries are of great use in enabling the company to maintain its service, as the power-house capacity is small and the power-house cannot of itself keep up the train movement during the heavier periods. The storage batteries are badly run down after four years use. Undoubtedly, with a modern power-installation, the showing made at the Baltimore terminal would be much better. Unfortunately, space limitations prevent the modernizing of the power plant.

The locomotives have a free-running speed of 20 miles per hour and can move a 3,000-ton train on a level, clean track, requiring 2,200 amperes of current at 560 volts, this decreasing to 900 amperes when a speed of 10 miles per hour is reached. They are capable of moving 1,400 tons on a 1% grade. The earliest locomotives were of the gearless type, weighing 96 tons each; the later locomotives are geared. The heavy trains are handled by two locomotives coupled together, controlled from the front locomotive. Only one man is required to handle the locomotive. The system of operation is to keep the locomotives available for service in the yards at the western end of the line. When a train approaches the electrified section a signal is sent from the despatcher's office by means of an electric bell, when the locomotive proceeds to the end of the electrified section and couples to the train as soon as it appears. When the train is pushed through to the end of the electrified system, the locomotive comes back light to its station in the yards. The locomotives have been somewhat expensively maintained in the past, but careful management is now bringing these costs down and it is to be expected that the next year will show a largely reduced cost. Even under the best circumstances, the electric locomotives and the power-houses are subjected to very severe usage. Only one train is on the line at a time and the trains are of extremely variable weights. The power-house is alternately running light and overloaded and the electric locomotives are subjected to severe corrosive action from the gases which rise from the steam locomotives at the heads of the trains pushed through the tunnels. The locomotives, besides, are worked on what is practically switching service on a grade.

NORTH SHORE RAILWAY

This was formerly the North Pacific Coast railroad, a narrow gauge steam line running north from Sausalito on the promontory north of and just across the harbor from San Francisco. A frequent ferry service is maintained from San Francisco to Sausalito and there is considerable traffic to Sausalito and neighboring towns of an excursion and commuter type, besides a fair amount of tourist traffic to Mt. Tamalpais, to the top of which there is a mountain road connecting with the North Shore. The road at the time of the electrification operated a line from Sausalito to Cazadero, 87 miles, with branches to Mill Valley and San Rafael.

The road went into new hands about 1902. Cheap water power was available and coal was high, so the new management decided to electrify the lower end in order to take care of the suburban and holiday traffic economically. At the same time an outside rail was put down along the track to be electrified in order to provide a broad-gauge track for electric trains and to keep the narrow-gauge track for their through steam trains. In addition, the upper end of the road was extended. 13.69 route miles of double track was electrified at the lower end, a third-rail direct-current installation being provided.

Current is purchased from the Bay Counties Power Company. The power is generated by water turbines and is transmitted 180 miles over a 50,000-volt transmission line. The voltage is dropped at a distributing station to 4,500 volts at which voltage it is distributed to the sub-stations along the railroad. An auxiliary steam plant is provided to supply current in case of trouble with the transmission line and this power-plant has a reserve capacity in order to allow of current being supplied to other local consumers. The third rail within the towns is carried on reconstructed granite insulators carried on the ends of long cross-ties; the entire right of way within towns being fenced to prevent the entrance upon the right of way of unauthorized persons, who might come into contact with this rail and be injured. In the country sections, the third rail is entirely exposed and a very cheap installation is secured by carrying the rail upon insulating wooden blocks sawed from the ends of cross ties. No extra-long ties are used in the country sections, but the third rails for both tracks are placed between the tracks on the wooden blocks, the blocks being long enough to span between the ends of neighboring cross-ties on the two tracks and being spiked down to these ties. On single-track sections a block of wood is embedded in the ground opposite the end of the tie and the insulating block spiked at the ends to this block and to the end of the tie. An aluminum rod carried in a trough surrounded by pitch, follows the track as a feeder.

Four and five car trains are used, each train carrying two motors. This property is now controlled by the Santa Fe.

SOUTHERN PACIFIC RAILWAY

The Southern Pacific main line from the East to San Francisco, terminates at Oakland, passengers being carried into San Francisco by ferry.— much the same arrangement as exists in New York with all of the railroads except the New York Central and the New Haven. In addition to the through terminal, there is a terminal for a large suburban traffic on a separate mole in Alameda, to which access is had to San Francisco by ferry lines. These suburban lines serve Oakland, Berkeley, San Jose and a number of other towns which are of themselves important and which are also used as places of residence for a large proportion of the people doing business in San Francisco. A distinctly suburban service is handled for about a 7-mile radius, stations being 4 miles apart. This suburban service is said to handle more passengers than any in the country, with the exception of the Illinois Central suburban system out of Chicago. The Southern Pacific at one time enjoyed a monopoly of this traffic, but some of it has been absorbed by the San Francisco, Oakland & San Jose railway, popularly known as the Key Route, an electric line operating 30 miles of road from a terminal on the Oakland side of the harbor (connected by ferry service to San Francisco) to Berkeley, Piedmont, and Oakland. The first Key Route trains were opened to the public on October 26, 1903, and the road was finished in the middle of 1904, a very fast service at 20-minute intervals being established between the points on its route by multiple unit trains containing a variable number of motor coaches and trailers. It is currently reported that the Key Route has offered the Southern Pacific very severe competition and is eating into their traffic. In addition to being enabled to meet this competition, as coal costs $8 or $9 a ton on the Pacific coast and as electrification will largely decrease their consumption, there is every reason to believe that a saving will be effected to the Southern Pacific by electrical working.

In 1903, the Southern Pacific retained Mr. A. H. Babcock (who carried out the North Shore electrification) to prepare plans and estimates for the conversion of their local roads in Berkeley, Oakland, and Alameda. In December, 1906, plans were adopted for the replacing of the steam system with electric traction on all of the lines running out from the Alameda mole, the lines covering 14.5 miles of track, consisting of a narrow-gauge line to High Street, the broad gauge line through Alameda to Fruitvale and on to Melrose, and the Oakland broad gauge line running to Fourteenth and Webster Streets.

The power-house is being built in Alameda, two 5,000-kilowatt turbine units being installed. A direct-current 1200-volt trolley system is to be installed. The preliminary estimates covered a contemplated expenditure of $1,250,000. It was announced that all suburban traffic would be diverted from the Oakland to the Alameda mole and the present steam lines running to Oakland and Berkeley would be electrified. It was later given out that one of the two existing parallel steam lines running between Oakland and San Jose would also be electrified, this work being carried on in connection with the building of a cut-off across the southern end of the Bay for steam service to avoid ferrying freight trains.

The contracts for the equipment have been let and the construction of the power-station begun. Contracts let are announced as aggregating $1,881,600 expenditure, and the total work is now estimated to cost $2,500,000,— the original program calling for a $1,250,000 expenditure having been augmented. It is probable that the system will be in operation within the next year.

In addition to this suburban electrification, various announcements have appeared in the press from time to time to the effect that the Southern Pacific is contemplating the electrification of its Sierra Nevada division, the daily coast papers in the fall of 1907 announcing that the line would be electrically equipped, as a saving of 13% in the operation would result. Vice-President Kruttschnitt has announced through the press that the railroad is investigating the possibilities of such an electrification and that Messrs. Sprague and Babcock have been placed on a commission to study the same. The electrification contemplated is that of the Sacramento division between Rockland and Sparks. This is a single-track mountain division, over which the entire Southern Pacific traffic to the coast passes. In 83 miles there is a 7,000-foot rise in elevation. The line is full of very sharp curves, is built on the sides of mountains with heavy grades and cuts, and along it there are 31 miles of tunnel and snowsheds. It is subjected to a very heavy but irregular traffic and acts as a throttle upon the whole system. There are three possible ways of overcoming the difficulties,— namely, to tunnel the mountains low down, to add an additional track, or to electrify. Either of the first two would be extremely expensive and it is believed that electrification would permit them to work the existent track to a greater intensity. What decision, if any, has been reached, has not yet been announced.

MICHIGAN CENTRAL RAILROAD

This is a tunnel electrification installed for the purpose of operating trains through a tunnel where the gases from locomotives would be obnoxious and positively dangerous. The main line of the Michigan Central crosses the Detroit River into Canada, at Detroit. At present their entire freight and passenger traffic must be ferried across this river, an operation which causes a loss of time and is expensive. The Michigan Central is at present driving a tunnel underneath the Detroit River, connecting Detroit and Windsor, Ontario, through which their entire traffic will be handled. The tunnel contains two tracks in separate iron tubes 65 feet below the river surface. The contemplated electrified-tunnel zone will be 3.6 miles long, and will comprise, with the yards on either side, 15 miles of electrified single track. Power will be purchased from the Detroit Edison Company; a 60-cycle 4,400-volt current will be delivered at the sub-station, where two 1,000-kilowatt motor generator sets will convert the current to 650-volt direct current.

A third-rail construction will be adopted. It is said that this rail will be carried overhead in the tunnel.

Six 100-ton direct-current locomotives are on order for this tunnel, each locomotive being equipped with two 300-horse-power commutating-pole geared motors to each truck, or 1,200-horse-power to a locomotive. Each locomotive will be capable of hauling a 900-ton train up a 2% grade at 12 miles per hour. The heavier trains will be double-headed, the locomotives being equipped with multiple control.

An electric lighting and pumping plant is to be installed. Alternating current is to be used on the lighting circuits. Two circuits are used in each tunnel so that only one-half the lights will go out in case of a break in a circuit. Water from the tunnel will be pumped by five motor-driven centrifugal pumps each driven by an induction motor operating on 4,400 volts. A storage battery of a capacity sufficient to operate the station for one-half hour is to be installed. In case the current supply is interfered with and it is necessary to carry the load on the battery, the lighting and pumping circuits will be supplied from a 50-kilowatt motor generator set driven from the battery.

GRAND TRUNK RAILWAY

This is an electrification applied to the tunnel underneath the St. Clair River, between Port Huron, Michigan, and Sarnia, on the Canadian side,— through which the entire main-line traffic of the Grand Trunk railroad passes. Formerly, trains were hauled through the tunnel by five steam locomotives specially designed, these locomotives hauling 800 to 1,600 cars through the tunnel daily. A great deal of trouble was experienced in the operation of the tunnel, the steam trains frequently stalling. The heavier trains had to be cut in half to put them through the tunnel and several accidents in the tunnel occurred, in one of which a number of lives were lost from asphyxiation. In 1905, the electrification of the tunnel was decided upon and it is now in complete operation.

The electrification extends over 19,348 linear feet, of which the tunnel proper forms 6,032 feet. The tunnel is single-tracked. The maximum grade is 2%. A small yard is provided at each end for the storage of trains awaiting passage through the tunnel.

A single-phase system is installed, the conductors being carried on bridge work overhead. Bridges are 260 feet apart. The power-house contains two 1,250-kilowatt turbo-generators. Line voltage is 3,000.

Six electric locomotives were provided, each capable of exerting a draw-bar pull of 25,000 pounds on a 2% grade, and of hauling heavy trains at the rate of 10 miles per hour. The locomotives are equipped with double end multiple control and each locomotive carries three 250-horse-power single-phase motors. The heaviest trains are now hauled through the tunnel without being broken into sections, although such trains require double heading with locomotives. The capacity of the tunnel is estimated to be raised from twelve 1000-ton trains per day to thirty-five 1000-ton trains per day. The locomotives carry a single operator and, in addition to relieving congestion, a saving in operation is effected. Twenty-five tons of cheap run of mine coal are consumed daily under electrical working, against thirty-five tons of anthracite under steam-locomotive working costing $5.75 free on board Buffalo.

GREAT NORTHERN RAILWAY

The Cascade Tunnel on the Great Northern, one of the highest points on the road, is a single-track tunnel and acts as a throttle upon the entire system, the traffic over the road being limited by the traffic which can be put through this tunnel. It has obviously become a matter of good policy to adopt any system which might admit of a greater movement through the tunnel than under steam operation. The tunnel measures 14,400 feet from portal to portal and has a uniform grade of between 1.6 and 1.7%, the eastern end being 240 feet higher than the western. The interior of the tunnel has become so coated with soot that it drops upon the rails and makes them so greasy that the tractive effort of the locomotives is reduced within the tunnel beyond the reduction due to the grade. A three-phase system is being installed.

The generating station is a hydraulic one located on the Wenatchee River 30 miles away, power being brought to the tunnel by a 33,000-volt transmission line. Two overhead working conductors carrying two

Courtesy Westinghouse Electric & Mfg. Co.

New York, New Haven & Hartford Railroad — Electric Locomotives Hauling Heavy Passenger Train.

legs of the 6,600-volt, three-phase current,— the track return forming the third leg. Only the tunnel is to be electrified at first, but the press announces that if it is successful the whole 60-mile section on each side of the tunnel will be electrified. This section ascends 30 miles to the tunnel on one side and descends 30 miles on the other.

Four 100-ton three-phase locomotives have been ordered for use on this section. Each locomotive is equipped with four three-phase 325-horse-power motors and is capable of hauling a 500-ton train up a 2% grade at 15 miles per hour. The motors are geared to the axles. The motors will work at constant speed while going over the line and, while descending grades, will feed current back into the line.

BOSTON & MAINE RAILROAD

In 1902, the Boston & Maine electrically equipped their branch between Concord and Manchester. This is a single-track line 16.27 miles long and was equipped with standard direct-current trolley-line construction. Single cars to three-car electric trains are run on the branch.

ERIE RAILROAD

This road has experienced very severe competition around Rochester from the electric interurban lines. It is said that their local passenger traffic fell off under this competition to about 10% of its ordinary volume. The passenger traffic over the line has largely been of an interurban character, although some portion of the traffic is through passenger traffic. In order to regain their traffic, in the summer of 1906, contracts were made for the electrification of 34 miles of single track, in addition to sidings. This comprises the main line from Rochester to Avon, 19 miles, and 15 miles of branch line thence to Mt. Morris. Sidings are located every three or four miles.

Power is purchased from the Ontario Power Company which generates its power with water wheels at Niagara Falls and delivers the current to the Erie railroad sub-station over a 60,000-volt transmission line. A single-phase system is adopted, there being only one sub-station, or "transforming station" properly called (located at Avon) where the 60,000-volt current is dropped to 11,000 volts by three 750-kilowatt static transformers and delivered to the line at this voltage. The working conductor is suspended from a $\frac{7}{16}$-inch steel catenary messenger, carried over insulators on the ends of steel brackets extending from wooden poles. The working conductor is 22 feet above the track and is of No. 000 grooved copper. The messenger is of 7-strand, $\frac{7}{16}$-inch galvanized steel wire, with a tensile strength of 22,500 pounds. The hangers are ⅝-inch rods 10 feet apart. Pole spacing is 150 feet. Every bracket is grounded to the rails so that in case an insulator fails, an immediate short circuit results. Steady strain insulators are placed at the bottoms of the brackets. At places where sidings occur, a span construction is adopted. There are yards at Rochester and Avon, where three or four parallel tracks occur, that are electrified.

An ingenious line construction is adopted for these yards. Steel poles are set up at the outside of the tracks and a messenger cable suspended between, from which messenger is suspended by hangers a straight piece of T-iron spanning the tracks and attached to the poles at the ends. This T-iron carries insulators over which pass messengers from which the working conductors over the tracks depend. Section-insulators are installed at intervals.

Each motor car is equipped with four 100-horse-power single-phase motors and is designed to maintain a 24-mile-per-hour schedule with one stop a mile. Through passenger trains and freight trains are still handled by steam. For the electrically-operated local service, six round trips per day between Rochester and Mt. Morris and nine round trips per day between Avon and Mt. Morris have been substituted in lieu of a service of three trains per day under steam operation. The first regular trip over the line was made on January 27, 1907, and the line was opened for traffic shortly thereafter.

The Erie is rumored to be contemplating the eventual electrification of its suburban service out of its Jersey City terminal. In 1906, a commission was appointed to study this electrification, those appointed on the commission being Messrs. Graham, Arnold, Stillwell, Williams, and Morrison.

DELAWARE & HUDSON RAILROAD

In 1907, the Delaware & Hudson electrified a section of its road between Ballston and Saratoga, New York, for use by the Schenectady Railway Company, in order to supply a link in their route from Schenectady to New York. This was formally opened on July 3, 1907.

The railroad bed and track construction for this line are new, a double track being laid at the edge of and upon the Delaware & Hudson's right of way between Ballston and Saratoga. A direct-current overhead-trolley center-pole bracket single-messenger three-point suspension-catenary construction was adopted. Poles are spaced 100 feet apart. The messenger is ⅜-inch galvanized steel A No. 0000 trolley is used. A 500,000-cir. mil. stranded-copper feeder is installed and a return feeder of the same size is installed, connected with the tracks at every tenth pole. Standard 40-ton interurban cars are used, each equipped with four 125-horse-power motors with double-end control. These are capable of making 50 miles per hour on level track.

WASHINGTON, BALTIMORE & ANNAPOLIS RAILWAY

A portion of this road was formerly a steam road affording connection between Annapolis Junction and Odenton on the Baltimore & Ohio's and the Pennsylvania's main lines between Baltimore and Washington and the city of Annapolis, Maryland. The Company, starting with an electric road from Washington to Laurel, Maryland, as a nucleus, determined upon building a high-speed electric road between Baltimore and Washington with a branch to Annapolis. After various ups and downs, during which the road changed hands several times, it was finally completed, a new road-bed being built between Washington and Baltimore and the Annapolis, Washington & Baltimore steam line acquired and electrified to afford their connection to Annapolis.

There is a heavy interurban traffic between Baltimore and Washington, which was formerly taken care of by an excellent steam service on the Baltimore and Ohio and the Pennsylvania railroads. The two roads afforded hourly service between the two cities. The electric road competes with 123 steam trains daily, and to attract traffic it has been necessary to put on a high-grade service and to make the distance between Washington and Baltimore in one hour. The road comprehends an equivalent single-track mileage of 96.33 miles of which 20.5 is the old steam line.

A single-phase system is installed. The power is purchased from the Potomac Electric Company of Washington and delivered over a 33,000-volt, three-phase transmission line to a transforming and distributing station at Annapolis Junction. The power is said to cost them about 2 cents per kilowatt hour, or 7 cents per car mile. A single-messenger catenary-suspension pole-bracket construction is employed for the alternating current sections. Poles are 150 feet apart. The messenger is ⅜-inch steel wire, the trolley No. 0000 copper. Hangers are 16 feet, 8 inches apart. The working conductor is carried 19 feet, 6 inches above the rails on the main line and 21 feet on the Annapolis branch, this latter height being adopted on account of the passage of freight trains over the line. The cars operate on direct current within the city limits of Baltimore and inside Annapolis and Washington. In the latter two places, local regulations prohibit the using of the track rail as a return, and an overhead return is provided.

The motor cars are each equipped with four 125-horse-power single-phase motors. The trains at present are run hourly between Annapolis and Baltimore and between Baltimore and Washington. Two trains an hour over each line will shortly be run. Baggage and mail are carried on the electric cars. We were informed that the company possesses an electric locomotive and hauls freight cars by electricity, but we noted that the freight yard at Annapolis is not electrified and that freight is evidently handled by steam, whatever may be contemplated for the future. Since the road was opened, it has carried a considerable traffic, which is said to be constantly increasing.

BALTIMORE & ANNAPOLIS SHORT LINE

This is a line of road running between Annapolis and Baltimore over a single track 25¼ miles long, in addition to which there is a branch 4 miles long from Annapolis to a seaside resort frequented by Baltimore excursionists, known as Bay Ridge. We are told that, upon the electrification of the Annapolis, Washington & Baltimore through acquirement by the Baltimore, Washington & Annapolis, the latter road took all the passenger traffic between Baltimore and Annapolis. The Short Line consolidated with the Maryland Electric Railways Company about two years ago and electrified, it is said, in order to hold its share of the traffic. Under steam operation the road ran 7 three-coach trains a day each way. The fastest time between Baltimore and Annapolis was made in 45 minutes by a train making five stops, or a mean speed of 33.7 miles per hour. The running time of the locals was one hour, with 15 stops. Under electrical working the trains will be run on an hourly headway, the express trains making the run in 45 minutes and the locals in 55 minutes.

The company buys power from the Consolidated Gas, Electric Light and Power Company of Baltimore, which delivers current through a transmission line carrying current at 22,000 volts. The current is transformed and distributed from one station, no sub-stations being provided, 6,600-volt single-phase current being supplied to the line. A single-pole bracket single-messenger catenary-suspension construction is used, similar to that used on the Washington, Baltimore & Annapolis. Poles are placed 120 feet apart. The working conductor is No. 000 and is located 22 feet above the rails. A steel wire for lightning protection is carried along the top of the poles and is connected to the track at intervals and also grounded to buried plates.

Trains weighing 50 tons, each equipped with four 100-horse-power motors are used on the line. The current is collected by a shoe carried on a diamond pantagraph, instead of by means of a trolley as on the Washington, Baltimore & Annapolis.

INTERNATIONAL RAILWAY COMPANY

As a part of their system covering the territory around Buffalo and Niagara Falls, the International Railway Company operates a line about 16 miles long connecting Buffalo and Lockport. A portion of the line is a former steam track leased from the Erie Railroad and electrified by the predecessors of the International Railway Company.

The line is equipped with standard direct-current trolley construction and in addition to handling the interurban traffic, carries all of the freight consigned to Lockport from the steam-road terminals in Buffalo. The freight is hauled in standard freight cars as delivered by the steam railroads. Electric locomotives are used for hauling this freight, the locomotives being able to haul 15 to 20 loaded freight cars. Daily freight traffic amounts to about 40 carloads, and may reach 60 at times.

Power is purchased from the power companies at Niagara Falls. A reserve steam plant was built at Niagara when the road was originally equipped.

As they have no data over the road for steam haulage, the officials of this company were unable to inform us as to the comparative cost of handling this freight traffic by steam and by electricity. The maintenance of electric locomotives on this line has been extremely low. We have quoted their record in a preceding section of this report.

NORTHERN PACIFIC RAILROAD

The Northern Pacific has a branch between Everett and Snohomish, Washington, 9 miles long, over which two trains each way per day were run, the traffic being light and not warranting more trains being put on. The expense of operating the passenger service is said to have used up the entire passenger earnings, and the passenger service was conducted merely as a convenience to the public.

The local street-railway system in Everett was desirous of extending its lines to surrounding towns, and particularly to build a connection between Everett and Snohomish. The topography is rough, and to have constructed a line would have been very expensive. Accordingly a lease was made of the Northern Pacific branch and the line electrified to supply the interurban section, an hourly service being put on. The freight traffic was retained by the Northern Pacific and operated with steam locomotives.

In the preliminary figures, it was calculated that $2,200 per annum per mile would be taken in from passengers, in spite of a reduction in fares from 3 cents to 1½ cents per mile. According to the press, these expectations have been largely exceeded.

CHICAGO, BURLINGTON & QUINCY RAILROAD

This road operates an electrically-equipped branch line between Deadwood and Lead, South Dakota. It is an overhead-trolley line equipped with three motor cars and two trailers.

COLORADO SPRINGS & CRIPPLE CREEK RAILROAD

This steam road operates certain electrified divisions through Cripple Creek, Anaconda, Elkton, Goldfield, Independence, and Victor, Colorado, and steam cars to other places. The road comprehends 57 miles of steam track and 17 miles of electrified track.

CINCINNATI, HAMILTON & DAYTON RAILWAY

The branch line between Findley and Delphos, Ohio, about 20 miles in length, which used to be important, but which through acquirement of other trackage has been left off the main line and become only a local line, has been electrified by the Cincinnati, Hamilton & Dayton.

FONDA, JOHNSTOWN & GLOVERSVILLE RAILWAY

This is an interurban electric railawy connecting Gloversville, Fonda, Schenectady, Johnstown, and Amsterdam. In the formation of the company, an electric road and a steam road were acquired and the electrically-worked track extended. A portion of the steam track has been electrified to form a link in their electrical section, although steam trains are still operated over it, the road being chartered as a steam road; 33 miles of steam road are operated and 85 miles of electric.

LOS ANGELES & REDONDO RAILROAD

In 1890, a narrow gauge steam road paralleling the Santa Fe, was built between Los Angeles and Redondo, California (18 miles). In 1902, the road fell into the hands of a new company who saw that its proper field would be operation as an interurban electric road. The gauge was broadened and the line electrified, standard direct-current construction being employed.

The line owns three shipping wharves at Redondo, the trackage over which terminal is electrified. Steam locomotives were formerly used there for switching purposes, but have been replaced by small electric locomotives. An article in the Street Railway Journal of April 30, 1904, says, concerning the Los Angeles & Redondo:

"This Company has proven that it can handle car-load freight, however, with its electric locomotives, at a less outlay of power-consumption than it had previously experienced in steam locomotives, and, aside from all this, there is the material advantage of saving in labor-cost, as two men can handle the trains in lieu of four, and the services of a high-priced locomotive engineer are dispensed with."

According to 1908 returns, the road operates 84.33 miles of electrified track and possesses one steam locomotive and two electric locomotives for handling freight.

EVANSVILLE SUBURBAN & NEWBURGH RAILWAY

This was an unimportant steam road out of Evansville, Indiana, operated by steam locomotives for 15 years. In 1904, it was equipped with overhead trolley and the necessary rolling-stock bought for passenger service. In 1905 the line was extended. It comprises at present, 25 miles of road and 3 miles of siding. Freight is still handled by steam.

NATIONAL CITY & OTAY RAILWAY

This is a former steam suburban line extending from San Diego and National City to Chulavista, about ten miles,— which track has been electrified. The controlling company also operates the Coronado railroad, a minor steam line 22 miles long.

SAN DIEGO, PACIFIC BEACH & LAJOLLA RAILROAD

This narrow-gauge line between San Diego and Lajolla is being converted into an electric trolley line.

VISALIA & LEMON GROVE RAILWAY

This is a subsidiary line to the Southern Pacific in California, which comprises 23 miles of track, of which 10 miles were formerly operated by steam. A single-phase system has been adopted for the road. It is particularly interesting in that 15-cycle equipment is used.

CINCINNATI, GEORGETOWN & PORTSMOUTH RAILROAD

This was formerly a narrow-gauge steam line extending from Cincinnati to Georgetown, Ohio, 47 miles. It was acquired by the Appleyard Syndicate which operated a number of roads connecting Cincinnati, Toledo, Columbus, Ohio, and Wheeling, West Virginia, and was electrified to form a link in their system. At the time of electrification, it was changed to standard gauge and extended. Under steam, the operation of the road was expensive, and, at the time of its taking over by the Appleyard Syndicate, the depreciation of equipment caused the operating expenses to form an unusually large part of the gross expenses. After electrification, in place of the two passenger trains per day run under steam service, an hourly service each way was put on and the passenger rates reduced one-third. The following figures were given out, concerning the operation of the 47 miles of road from Cincinnati to Georgetown:

Month	Gross Earnings	Operating Expenses	Net
December 1900....	$ 6,669.00	$5,633.00	$1,036.00
December 1901....	8,818.00	5,686.00	3,133.00
December 1902....	10,000.00	5,900.00	4,100.00

During December 1900, it was operated as a narrow-gauge steam road; during December 1901, the same, but under new and progressive management. December 1902 was the first month of electrical operation. The receipts for the year ending July 31, 1903, were $130,000 against $105,000 for the preceding year under exclusive steam operation. Freight was at first handled entirely by steam, but since two 50-ton 300-horse-power electric locomotives have been acquired, the freight is handled partly by them.

DAYTON, LEBANON & CINCINNATI RAILROAD

This road was a former steam road operating from Dayton to Lebanon, Ohio, with a single-track mileage of 26 miles. It was converted to an electric trolley road in 1904.

OHIO RIVER & WESTERN RAILWAY

This narrow-gauge steam line operating between Zanesville and Wheeling was converted to an interurban trolley road in 1904.

OHIO RIVER & COLUMBUS RAILWAY

This small and unimportant steam line was converted into an interurban trolley line in 1904.

YOUNGSTOWN & OHIO RAILWAY

This company, building an interurban electric road, secured a 99-year lease on 6 miles of the Pittsburgh, Lisbon & Western trackage, formerly operated by steam, and electrified it in order to get into Salem, Ohio.

CINCINNATI & NORTHWESTERN RAILWAY

This was a very small steam road operating from College Hill Junction to Mt. Healthy. It was acquired by the Cincinnati, Dayton & Toledo, an interurban road, and electrified by the latter in order to afford a connection into Cincinnati.

PEORIA & PEKIN TRACTION & TERMINAL CO

This was a combined electrically and steam operated road owning and operating 15 miles of trackage. It was acquired by the Chicago & Alton in 1905.

CHICAGO & GREAT WESTERN RAILWAY

In October, 1903, the Waterloo, Cedar Falls & Northern railway leased a 22-mile branch of the Chicago & Great Western railway, between Sumner and Waverly, Iowa, and in 1905, the Waterloo, Cedar Falls & Northern railway was acquired by the Chicago & Great Western. Under it are operated 89 miles of electrically and steam operated trackage. The equipment of the road comprises 85 electric and steam passenger cars and 2 electric and 3 steam locomotives.

KEESEVILLE, AUSABLE CHASM & LAKE CHAMPLAIN RAILWAY

This is a small line extending from Port Kent in Essex County, New York, to Keeseville,— connecting with the Delaware & Hudson. It was built to supply freight facilities to pulp-paper and horseshoe-nail mills along the Ausable River and was formerly operated by steam. Owing to its rendering the Ausable Chasm accessible to tourists, the passenger traffic became a very large factor with it, and it became evident that its operation could be most profitably conducted as an electric-railway proposition. In addition, cheap water power was available. In 1905, it was changed from a steam to an electric road operating 6 miles of track, and is equipped with one electric and one steam locomotive and five cars. It is a third-rail direct-current type.

HOCKING VALLEY RAILROAD

This railroad operates an electrical service between Dundas and Jackson, Ohio, as the Wellston & Jackson belt railway (leased for 99 years) in addition to its through steam service over the line into Jackson.

SALT LAKE & OGDEN RAILROAD

This was formerly operated as a steam road, but, in 1904, was purchased by new interests and money was raised to convert it into an electric road and provide for its extension from Farmington to Ogden, Utah. Thirty-eight miles of former steam road are now in process of conversion.

NEWTON & NORTHWESTERN RAILWAY

The Fort Dodge, Des Moines & Southern railway, an interurban railroad company, in 1906, purchased the Newton & Northwestern railway (this being a steam road running northwest from Newton, Iowa, through Boone to Rockwell City, Iowa, a distance of 42 miles), and electrified a portion of it, adding about 25 miles of new line on each end to Fort Dodge and Des Moines respectively. A branch line 5 miles in length was built from Kelly to Ames.

The electrified section was equipped with ordinary direct-current trolley construction. According to 1908 returns, the steam line is now 102 miles in length, of which 37 miles between Kelly and Lanyon have been electrified. The road owns and operates at present, 85 miles of electric track. A joint steam and electric service is maintained, freight being handled by steam.

CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

This road electrified a portion of its Evanston branch running north from Wilson Avenue, Chicago, to afford an extension to the Northwestern Elevated railroad, which now runs its trains north over this track, under a trackage agreement.

COLORADO & SOUTHERN RAILWAY

The Denver & Interurban, which is a part of the Colorado & Southern system, has been electrified with the single-phase system. The electrified line extends from the outskirts of the Denver City limits to a junction point known as Louisville Junction, thence two branches pass to Boulder, forming an almost circular loop. In addition, there is a spur from El Dorado Springs to the nearest point on the Marshall branch. In all, forty-four miles of track are electrified.

Outside the terminal cities, the single-phase system is used, a single-messenger catenary construction being employed. Most of the line is bracket construction, but a part is cross-span. The brackets are attached to the poles by collars, instead of being bolted, and a new type of steady-strain insulator, which will drop off clear of the trolley wire in case an insulator breaks, is used on curves. Catenary wire cross-spans are used instead of bridge work, where span construction is resorted to. The messenger is $\frac{7}{16}$-inch galvanized steel wire. The trolley wire is No. 0000 phono-electric, and is carried 22 feet above the rails. Poles are spaced 120 feet apart on tangents. There are two 1,000-kilowatt turbo-alternators in the power-station, delivering single-phase current.

Within the city limits of Denver, the cars operate over the tracks of the Denver Tramways Company, operating on direct current,— and 1.5 miles of direct-current line have been provided through the city of Boulder for operation there.

GENERAL

It will be seen that the electrifications in the United States extend over a great variety. The smaller electrifications are of no consequence to the terminal problem presented in Chicago, but are simply presented to show the elasticity of electric equipment ,which can handle the very heavy terminal service of the New York Central, on the one hand, and the light services indicated in the minor electrifications, on the other. In addition to these electrifications, the numerous and generally profitable conversions of numerous dummy lines throughout the country, should be borne in mind as well as the electrification of the elevated-railroad systems in various cities of the United States,— which electrifications have, without exception, afforded a large saving in operation to the companies concerned.

The elevated-railroad electrifications are of particular importance because they handle a traffic similar to that handled by the more busily employed suburban services afforded by the steam roads, and the electrification of the suburban services would be along similar lines to the electrification of the elevated railroads. At the time the work was consummated, the electrification of the elevated railroads was a much larger problem than would be the electrification of the steam-railroad terminals in Chicago at present. At that time, the apparatus and devices which they were called upon to use were new and in many cases untried. What the maintenance on this apparatus would be, could not very well be predicted, and the power-requirements were much larger than in any work hitherto attempted.

Electric traction for the steam roads, in the present instance, has passed out of the experimental stage. Such experiments as are in progress are to determine the choice of the best system or to prove certain economic contentions regarding electrical equipment. The physical possibilities of electrification cannot be questioned. The varying conditions under which it has been applied in existing electrifications cover about all the phases of the Chicago situation, with the exception of freight-handling, and in this direction there is merely an extension, and not an excursion in an entirely new direction. While the entire problem offered by the electrification of each terminal in Chicago is a large one, it is a large one merely because it amasses a number of smaller ones which have already been paralleled. It is interesting to recall that the power-stations of the elevated railroads in Chicago are each of rather more than sufficient capacity to take care of an entire terminal power-demand under electrification.

Should one power house be provided for the working of all the terminals of all the railroads in Chicago under electricity, it would mean a power-house of a size of which there are no fewer than six in the Island of Manhattan alone,— to say nothing of the other large power-houses in Greater New York.

As to finances, the Pennsylvania railroad is spending more money to provide a terminal in New York City, than would be required for the equipment for electrical working of all the railroads within the city limits of Chicago.

BRITISH ISLES

LONDON

In London there has existed for a long time a sort of belt line within the center of the city for carrying local passenger traffic. It is popularly known as the "Inner Circle." This is carried in shallow-level subways and the trains thereon were formerly operated by steam. The deep-level subways are tube roads and have always been operated by electricity. The Inner Circle is the joint property of the Metropolitan Railways and the Metropolitan District Railways, with a joint mileage of 128 miles. The smoke was obnoxious and traffic became congested. Several commissions were called to pass upon the situation and a recommendation was made for the electrification of the Inner Circle. The electrification was accordingly carried out about 1903. This belt also handles certain passenger suburban trains delivered to it by the steam railroads entering London.

GREAT WESTERN RAILWAY

This railroad owns a branch known as the Hammersmith & City railway branch which formerly delivered its steam trains to the Metropolitan railway, which hauled them by electricity over the Inner Circle. Because of its intimate connection with the Inner Circle, the Great Western railway decided upon the electrification of this steam branch. Its equipment was made to correspond with the equipment adopted upon the Inner Circle,— six-car multiple-unit trains being run upon 600-volt direct current collected from a 103-pound third rail, with an insulated return installed in the middle of the track. The trains accelerate at the rate of 1.6 miles per hour per second and consume 75 watt-hours per ton mile.

The electrification covers about 4 miles of double-track road together with terminals. It was put into operation in 1907.

LONDON & SOUTHWESTERN RAILWAY

This road has in operation an electrified tube line from Waterloo Station to a station near the Bank of England in order to get its passengers to a terminal in the heart of London.

LONDON & NORTHWESTERN RAILWAY

This is a standard steam trunk line operating suburban trains which are run through the underground tunnels of the Metropolitan district railway. The suburbans start from Broad Street in London and run on an open railway around the North of London to Willesden Junction, where they cross the main line of the London & Northwestern and run to Earl's Court. At Earl's Court Station, the underground attaches electric locomotives to the trains and hauls them the remaining portion of their journey through the tube, to Mansion House Station.

The through passenger service of the London & Northwestern is considered the banner service of the old world.

The management of the London & Northwestern is desirous of further development of its suburban traffic, but to do so would interfere with the through traffic which is already badly congested. Accordingly, they have adopted a plan of building an entirely new electric railway from the present terminus at Euston, to Watford, a distance of 17 miles in order to handle the suburban traffic and to give over the entire present trackage into the terminal to the through traffic. This suburban line will start beneath the present Euston terminus and will run below the existing main track in a subway until open country is reached at Kilburn, when the line for the remaining distance will be constructed partly by widening the existent right of way and partly by the construction of a new route. Parliamentary sanction for this work has been asked and the details announced to the public by Lord Stalbridge, at a semi-annual meeting of the stockholders, over which he presided in 1906. It is reported, at the present time, that the carrying out of this work is temporarily held up, owing to difficulty in borrowing the capital necessary to carry it out.

LONDON, BRIGHTON & SOUTH COAST RAILWAY

This railway, which does an important suburban business in the southern part of London in addition to main-line traffic, determined upon the electrification of its London line between London Bridge and Victoria Station in order to relieve congestion and to afford a more attractive service. At the end of 1904 it announced its determination to electrify four miles between Battersea Park and Peckham Rye, as an experiment. This is an inter-connecting link between main lines and is not necessary for through traffic. They announced that if their experiment should be successful, the line would be extended at both ends to London Bridge and Victoria Station. This extension was subsequently carried out and the equipment of their line over 12 miles of double trackage is just being completed, their expenditure being approximately $1,250,000.

Power is being supplied them from the London Electric Supply Corporation, with whom they have a 7-year contract. The single-phase system has been adopted, a single-messenger catenary suspension supported from steel bridges, being employed on the line. The car motors are of the Winter-Eichberg repulsion type. Delivery of the rolling-stock is expected in August 1908, and operation under electrical service shortly thereafter.

MERSEY RAILWAY

This is a double-track railroad operating in a tunnel from Liverpool under the Mersey River to the Hamilton Square Station in Birkenhead, and thence to other stations in the latter city. It handles a large passenger traffic between these two towns. It was opened to operation on January 20, 1886, a steam service being operated in the tunnel. The smoke and soot were extremely objectionable and large ventilating fans were installed to aid in the ventilation of the tunnel. A separate ventilating tunnel was run alongside the two-track tunnel and a large ventilating plant was installed. The ventilation of the tunnel was very expensive and used up all of the profits which might otherwise have come to the road. For a number of years preceding the electrification, no dividends were paid upon the stock.

Electrification of the road was determined upon in 1902, and on March 2, 1903, the last steam train was run in the tunnel, a complete change from steam to electrical working being made in a single day.

Current is supplied by a third rail at 600 volts. An extra insulated rail is furnished for the return current. Multiple-unit trains of various length are operated upon the road. Direct-current generators are installed for supplying the operating current, but alternating-current generators have also been provided, as the electrification of connecting lines is contemplated. In the first week's working under electricity, 125,272 passengers were carried, an increase of 37,619, or 45%, and an increase in the revenues of $1,390. The traffic on the other lines did not show a decrease. This we take as showing that increased facilities bring increased traffic.

For the first half-year's electrical working, the road reported an increase in receipts of $40,000. The number of passengers during this time increased from 2,844,000 to 4,153,000. The train miles run during the half-year were 400,000, as compared with 155,000 miles run under steam during the half-year ending December 31, 1902. The operating expenses per train mile under steam were 82¼ cents, as compared with 36.4 cents under electricity. Correspondence from London to the Street Railway Journal, in 1903, stated:

"The tide seems to have turned with the Mersey railroad. For some years this company has been working at a loss. At a recent half-yearly meeting it was stated that the number of passengers during the last half-year distinctly increased and the receipts have been steadily going upward, while before the electrification the receipts had been going steadily downward."

Dawson is authority for the following costs on this road under steam and under electrical working:

	1901 with Steam	1905 with Electricity
Locomotive cost per train mile, pence	13.653	6.29
Train lighting and cleaning per train mile, pence....................	1.665	0.580
Repairs and renewals of carriages and wagons per train mile in pence..	1.719	1.075

	1901 with Steam	1905 with Electricity
Train miles run	311,360	829,898
Total expenditures	£64,662	£69,036
Maintenance of permanent way	£6,055	£3,793

Further comparison in 1906:

Train miles	829,188
Total Expenses	£70,930
Increased train mileage	167%
Increase in total expenditures	10%

At the semi-annual meeting of the stockholders, held in the fall of 1904, W. J. Falconer, chairman of the Board of Directors, stated that the total number of passengers carried for the past six-month period exclusive of season ticket holders was....4,500,000
against....3,200,000
for the corresponding period in 1903, or an increase of 40%
Total receipts from passengers in the 6 months.... £33,715
against.... £26,136
for same period 1903, an increase of.... 29%
The number of passengers using season tickets increased, the receipts from this source being against £4,167
against.... £3,485
or an increase of.... 20%
From all sources, the receipts for the 6 months were £40,918
against.... £32,278
in 1903, or an increase of.... 25%
The working expenses for the 6 months were.... £33,591
against.... £32,061
for corresponding 6 months in 1903, an increase of only.... £1,530
But these expenses included the exceptional charges for pumping and ventilation. If they excluded these in order to afford a comparison between actual working expenses, the expenses would be for the 6 months £29,751
against.... £27,375
an increase of only.... £2,376
The train mileage for the 6 months had been 411,683
against 218,308
for the corresponding 6 months in 1903, so that they had been running something like double train mileage.
Excluding pumping and ventilation, the cost per train mile in 1903, in pence, during 4 months' steam and 2 months' electrical working was.... 30.1
while during the last six months the cost per train mile under exclusive electrical working had been in pence.... 17.35
equal to a reduction of.... 40%
If, however, they included pumping and ventilation charges, the cost per train mile for the half year in 1903, was, in pence.... 35.25
while the cost during the corresponding period in 1904 was, in pence.... 19.58

"These figures conclusively establish the superiority of electrical traction over steam traction, in dealing with such a railway as this." (Street Railway Journal, Nov. 5, 1904.)

NORTH EASTERN RAILWAY

This is one of the major railroads of England. They have a heavy suburban traffic tributary to Newcastle, which they decided to handle electrically about 1902. The working expenses on their lines were steadily going up and their receipts were stationary,— as is the case with most of the suburban operation in England. Thus, in London, in the 10-year period from 1895 to 1905, the operating costs for certain London suburban trains per train mile had risen from 66.5 cents to 82.5 cents, without any increase in receipts. The construction of certain electric roads in the vicinity of Newcastle and the projection of others, had proved a menace to the North Eastern suburban service, and it became necessary, if they were to hold this travel, to electrify such of their lines as might be brought into competition.

Newcastle is a large, industrial city, with seaside resorts at the mouth of the Tyne, about 8 miles distant, and a number of nearby country towns which are used for residence and points of excursion by a large number of people employed or living in Newcastle. In addition to the main line of the North Eastern, the company possesses a network of suburban lines connecting these points.

In addition to the electrification of their strictly passenger lines, the electrification of their Quayside branch line was undertaken. This line is used entirely for freight traffic. It passes along, or adjacent to, the water-front and gives service to a number of industrial plants. Its electrification was decided upon because steam operation has prevented the line being used to its full capacity, — owing to its being mostly in tunnels and on a heavy grade.

In addition to the electrification of existing steam lines, a new line connecting Gosforth and Ponteland has been built and electrically equipped from the start.

The electrification extends over 37 miles of single, double, and four-track line. Numerous junctions and cross-overs and a large amount of special track work are incorporated. The trackage electrically equipped initially amounted to 82 miles of equivalent single track. The mean distance between stations on the suburban line is about 1¼ miles.

Power is purchased locally. Third-rail equipment of standard construction is employed on all main trackage. Freight yards are equipped with an overhead trolley construction, two overhead wires connected in parallel being suspended over each track, from which current is collected by the electrical freight locomotives by a bow collector.

For the freight service on the Quayside branch, two electric locomotives are in use. The locomotives are of the geared type, weigh 50 tons each and are each provided with a four-motor equipment. They are capable of handling a 300-ton train (long ton) on a level, at 14 miles an hour, or can start a train of 150 tons on a grade of 1.27%, running up this grade under all conditions of weather at 10 miles an hour. Freight service on lines other than the Quayside branch, is handled by steam locomotives. Passenger traffic is handled in multiple-unit trains. The motor cars are equipped with motors of 600-horse-power capacity to each car. The ordinary train is made up of two motor cars and two trailers, each car seating 66 passengers and the entire train weighing 270 tons. The trains are run on a 15-minute headway with a 20-second stop at stations and the running-time has been reduced about 25% below that under steam operation. They run at a maximum velocity of 35 miles per hour, and at an average of about 22 miles per hour.

The first trains were put on from Newcastle to Benton in 1904. The entire electrification was opened to the public on March 29, 1904, and the full electrical service in July of the same year. In November, 1904, within 6 months of the inauguration of full electrical working, occurred the visit of the Channel Squadron to Newcastle, to which we have already referred. This put very severe demands upon the railroad, which were very ably met, by putting every electrical car owned by the railroad into operation the second day of the visit.

The capital required for the conversion of the line was $930,000. The chairman, Viscount Ridey, speaking of the electrification about two months after its opening to the public, announced that so far as profit and loss were concerned it was too early to speak, but that, taking the two weeks ending July 11, 1903, and July 9, 1904, for comparison, it was found that the passengers between stations had increased 25% and the money receipts 22% and that their newly electrified lines were satisfactory. Dawson has published the following figures covering the operation under the first 6 months with electricity, and that of the corresponding preceding 6 months under steam operation, stating that the steam costs are somewhat low as they are the figures for the entire line, while terminal costs always run higher than the average costs for a road:

	Half-year ending Dec. 1903 Steam	Half-year ending Dec. 1905 Electric	Per Cent Increase
Gross earnings	£129,000	£151,000	17.1
Running costs........	£42,761	£47,779	11.7
Ratio costs to receipts	33.2%	31.8%	....
Locomotive power costs per train mile	14.5d.	6.75d.	....
Passengers carried.....	2,844,000	3,548,000	24.8

The following figures are for February, 1905:

Mileage of trains.	92,541
Mileage of cars	254,938
Average number of cars per train.	2.75
Total energy consumed in kilowatt hours	647,140
Energy consumed per train mile kilowatt hours	6.933
Energy consumed per car mile in kilowatt hours	2.538
Average cost of power per car mile in pence	1.601
Engineers' pay per car mile in pence	.297
Conductors' pay in pence	.217
Total cost of traction per car mile in pence	2.115
Total cost of traction per train mile	5.7

Hon. John Lloyd Walton, chairman of the Board of Directors of the North Eastern Railway, stated to the stockholders in 1905, that "the further experience of electric traction of the Newcastle District has been entirely favorable, both practically and financially. In the last half-year of steam they had had 2,844,000 bookings, but with electric traction for the last half-year of 1905, they had carried 3,548,000 passengers, an increase in round-numbers of 25%. The gross earnings for the half-year 1903, when operated by steam, were £129,000, and for the corresponding half-year in 1905, when run electrically £151,000." The chairman further stated that while the running costs in 1903 for the half-year were £42,761, although their mileage had been doubled with electrification, the working costs for the corresponding half-year in 1905 were only £47,779.

Alexander Wilson, assistant general manager of the North Eastern railway, on May 6, 1905, before the International Railway Congress in its session at Washington, D. C., stated that "the North Eastern railway had been operating, for the last year, an electric suburban service in the Newcastle District, with the object of regaining the traffic from the competing tramways and to increase its amount. All the traffic has not been regained from the tramways, but the amount handled has been considerably increased. The reduction in expenses has resulted in a net revenue which more than covers the interest on the extra cost of installation necessitated by the introduction of the electric power. The current is being furnished at a reasonable price by power stations which do not belong to the railroad." (Street Railway Journal, May 13, 1905.)

The half-yearly report for 1906, states that further experience in electric working of the suburban lines in the Newcastle District has been favorable from a practical and from a financial point of view.

LANCASHIRE & YORKSHIRE RAILWAY

The Lancashire & Yorkshire system is one of the important railway systems in England. It has a heavy suburban traffic in the vicinity of Liverpool, the traffic under the steam operation extending out to Southport about 18½ miles distant, with occasional trains beyond. The line from Liverpool to Southport is almost straight, the stations at the Liverpool end are about one mile apart, and on the outer end at a further distance apart. A local service was operated as far as Hall Road, 7 miles towards Southport from Liverpool, and a combined local and express service operated beyond. The running-time from Liverpool to Southport was 25 minutes for the express trains and 54 minutes for the locals, and the running-time from Liverpool to Hall Road was 25 minutes. Under steam operation there were about 36 trains per day between Liverpool and Southport and about an equal number between Liverpool and Hall Road. The total train mileage before electrification per day was 1,900, this being increased under electrification to 3,200. Upon electrification the trains each way between Liverpool and Southport were increased from 36 to 65, and from Liverpool to Hall Road from 38 to 54. The running-time of local trains was decreased from 54 minutes to 37 minutes between Liverpool and Southport, and from 25 minutes to 17 minutes, between Liverpool and Hall Road.

A third-rail installation was adopted, direct current being supplied at 650 volts. The main station has a total capacity of 6,750 kilowatts, power being generated at 7,500 volts. There are four sub-stations which contain the converting apparatus of 1,800 kilowatts capacity each.

The passenger traffic is handled by multiple-unit trains. The trains in general comprise four cars, of which two are motors, the entire train weighing 140 tons. Each motor car is equipped with four 150-horsepower motors.

In 1906 the electrification was extended from Southport to Crossens, at which time the electrification comprehended about 60 miles of single track. An extension has been run to connect the railroad at Seaforth with the Liverpool Overhead and certain trains are now run over this elevated railroad to Seaforth and the balance of the way over the Lancashire & Yorkshire tracks. The additional power-requirements for these extensions have been secured by adding a storage-battery equipment to the present power-plant. In 1907, a further extension of the electrification was announced.

So far as the electrical equipment is concerned, the electrified road has operated very satisfactorily. There was, however, some trouble at the start with the main-power-station engines which delayed the road's being put into operation by electricity for some time. Two engines broke down, one having a broken shaft and another a cracked cylinder. In consequence, only 6 trains per hour were put on the service at first, later 9, and, on completion of repairs to the machinery, a complete service was put on. These failures were not failures peculiar to electrical traction, but might just as well have come to a power-plant owned by an industrial concern.

Regarding the electrification of this road, Sir George Armitage, one of the directors, at the annual meeting of the stockholders in 1906, stated that "a full year's experience had shown that the cost for working of trains, with proper allowance for depreciation and a more costly plant, were slightly higher per train mile than with the steam trains. They were, however, satisfied, as they had been able to do a greater amount of work, which would have been absolutely impossible under the old conditions. He also stated that they were contemplating further additions as the traffic was rapidly growing, and during the preceding year a very largely increased number of passengers had been carried by the electric trains. The whole system was working smoothly and well." (Street Railway Journal, March 3, 1906.) London correspondence to the Street Railway Journal (June 2, 1907,) states: "The results from electrification have been marvelously good."

One cannot but be struck by the close parallel existing between this electrified road and the Illinois Central, in so far as its suburban traffic out of Chicago is concerned. The Lancashire & Yorkshire run suburban trains to Southport, a distance of 18.5 miles, with occasional trains beyond, to Crossens. The majority of these trains are express trains, although some locals are run. The Illinois Central operates a suburban service to Harvey, a distance of 20 miles, of which the bulk of the trains are express trains, although a few locals are run. In addition, some trains are run a further distance to Flossmoor.

The Lancashire & Yorkshire runs about an equal number of trains, in addition, to Hall Road, 7 miles from Liverpool, the majority of these trains being locals. The Illinois Central, in addition, runs a number of trains to Woodlawn, 7.9 miles distant from Randolph Street, a majority of which are locals.

The Lancashire & Yorkshire line is almost straight from Liverpool to Southport and runs along the sea-coast a part of the way. The Illinois Central is almost straight from Randolph Street to Flossmoor, and runs along the lake-front part of the way.

Taking out the South Chicago and Blue Island branches, to which there are similar lateral branches on the Lancashire & Yorkshire, the number of trains operated by the Lancashire & Yorkshire under steam (144 per day) is about equal to the number operated by the Illinois Central on its north and south line (total number operated, excluding Blue Island and South Chicago, about 156 per day.)

There is even a physical connection between the Illinois Central tracks and a local elevated company, as with the Lancashire & Yorkshire. The Lancashire & Yorkshire stations were a short distance apart at the city and a further distance apart as the distance from the terminal increased, which is exactly the case with the Illinois Central.

The Lancashire & Yorkshire is in a country where coal is reasonably cheap, which is also the case with the Illinois Central of Chicago.

Indeed, so close is the parallel, that the average individual would have great difficulty in telling them apart if given the descriptions without the names. And if it is feasible and financially advantageous for the Lancashire and Yorkshire to have electrified its Liverpool suburban line, we do not see how it could be otherwise with the Illinois Central suburban lines out of Chicago. This aside from the detailed investigations which we have made.

MIDLAND RAILWAY

This railroad, in 1906, announced the electrification of its line between Heysham Harbor (which is on the new Midland route to Belfast), Morecambe, and Lancaster. While this is on one of their trunks lines, its electrification was prompted by a desire to experiment. The neighborhood is not one from which very great results are expected from a statistical point of view, but the application of electrical working to the section is of considerable interest, as it is believed that greater developments will arise from it in the future. The electrification extends over about 8.5 miles of double track, which, with sidings, gives a total electrified trackage of 21 miles of equivalent single track.

The single-phase system has been installed. The overhead wires are carried by steel lattice-work bridges in the yards, while on the line it is carried from two angles (with spacing-blocks between) spanning the tracks between poles at each side, to the sides of which the angles are clamped. A double-messenger wire is installed for each working conductor, the two messengers being carried on one insulator, however. The carrying conductor is suspended from the double messenger by triangular hangers and underneath the conductor, suspended to it by clips midway between hangers, is carried a contact wire of No. 000 copper. This construction was carried out in order to get rid of hard points in the contact wire and is similar to the later construction adopted by the New Haven. The contact wire is carried from 18 feet 3 inches to 13 feet 3 inches above the tops of the rails, and is installed in lengths of 2,400 to 3,000 feet, one end being attached rigidly to an insulator and the other end passing over a roller with a weight at the end in order to hold the conductor taut, independent of temperature variations. The contact wire is not carried directly over the center of the track, but its position is staggered at intervals, in order to produce uniform wear upon the collector-shoes. The bridges are connected by a steel cable in metallic contact therewith, which cable is grounded every half mile in order to get rid of induction in telegraph wires. The rails are bonded to form a return and are grounded to the sea. 6,600-single-phase current is carried on the contact line, no feeders being employed.

Power has been procured from an already existing power-house, where it is generated by gas-engine-driven alternators.

Through trains are not handled by electricity, the system having only been applied to the working of the interurban service. Standard coaches are hauled by motor cars the ordinary train being composed of one motor car and two trailers. Each motor car contains two 180-horse-power motors of the commutating-series type, geared to the axles, and capable of giving the cars a maximum speed of 55 miles per hour. Trains are run on a 20-minute headway between Heysham and Morecambe (5 miles) and a 15-minute service has been put on between Morecambe and Lancaster (4 miles). Trains as heavy as 161 tons (1 trailer, 7 motors) have been run.

Full service was inaugurated on this line with regular working, on June 7, 1908.

ITALY

The Italian roads in general are owned by the state although a number of lines are still under private ownership. Some of the lines are operated directly by the state, while others of the state-owned lines are operated by lessees. Coal is high in Italy, labor is cheap, a great deal of water power is accessible and, in addition, a good many of the railroads have rather heavier grades than common, and sharper curves,— all of which conditions favor the application of electrical traction. Some of the major applications of electrical traction in Italy have been made under extremely adverse conditions, and so favorable have been the results that large extensions are now being undertaken.

The investigation of electrification in Italy was first designed to cover the possibilities of electrification of secondary roads. By a note of December 13, 1897, a Royal Italian Commission was created for the purpose of inquiring "if the electric system of traction in its existent state is capable of application to lines with small existent traffic, with the ends in view of rendering less costly their operation, of better satisfying the public, of separating passenger and freight traffic, and of affording a larger number of trains daily." The report presented by this Commission states that in addition to directing their inquiries along these lines, they have considered the systems to be applied to different lengths of lines, the expenses of converting the road as well as those of establishing the generating stations on a mixed electrical and steam service, the security of public safety, the augmentation of traffic and the possible savings of operating expenses under electrification. A comprehensive report was presented by this commission in which, after a discussion of electric traction, they gave the results of their investigations into the cost of electric traction with storage-battery cars, with direct-current third-rail systems, and with alternating-current overhead systems. The applications of these systems to certain existing lines was discussed and estimates were made covering the costs of their installation and the probable savings to be expected therefrom. In addition, negotiations were entered into with the various railroads and industrial corporations concerned, and because of their activity, a number of experiments, both with storage batteries and with direct-current third rail, and overhead polyphase systems were undertaken. As a result of the interest awakened, the electrification of two main-line routes in Northern Italy was determined upon to test the desirability of electric traction and with the idea, should they prove a success, of eventually electrifying the lines throughout the whole of Northern Italy. Since then, constant progress has been made.

VALTELLINA RAILWAY

This line is operated by the Rete Adriatico (Adriatic Route), one of the two main lines in northern Italy. Sixty-seven miles of it were initially electrified in order to test the desirability of the electrification of lines throughout the north of Italy, but the electrification has been extended since and a further extension is now announced. The initial electrification section consisted of three lines extending from a junction point on Lake Como by the name of Colico. From Colico the three lines extend almost due north, due south, and due east to Chiavenna, Lecco, and Sondrio, respectively. The distances are: Colico to Lecco, 24.5 miles south; Colico to Sondrio, 25.5 miles east; Colico to Chiavenna, 17 miles north,— total, 67 miles. The lines possess numerous tunnels, fairly sharp curves, frequent gradients, the maximum grade being 2% The average distance between stations is 3 miles, while that for express trains is 8½ miles. Trains leave as seldom as one hour and 40 minutes apart; the shortest intervals between departures (at Lecco) being 14 minutes, and the shortest time between arrivals is 11 minutes. This is the reverse of conditions usually assumed as favorable to electrification.

According to Smith, (*Electric Railway Engineering*) the resident population along the track is 200,000 in the whole province, while only 54,000 live within a mile of the railroad. The towns are all small. Lecco and Sondrio each have 8,000 to 9,000 population; Morbegno, Colico, and Chiavenna each have from 4,000 to 5,000. The traffic receipts before electrification (half coming from passengers and half from freight traffic) amounted to $3,000 per mile, and only 80 cents per train mile. This is much below the average on other parts of the system, the average upon the whole of the Adriatic line having been $7,250 per mile, of which $3,150 came from passenger traffic. This $7,250 per mile means a revenue of $1.38 per train mile, so the traffic on the other parts of the system is nearly twice as remunerative as on the branches chosen for electrification. The average fare per passenger on the electrified section has been 24 cents, against 45 cents on the entire line. Thus the trial is being carried out under the severest and most unfavorable conditions (Against a $1.38 receipts per train mile, the average working costs in northern Italy are $1.03 per train mile, and of this, 15 cents is spent for fuel).

The three-phase system has been installed. Power is generated at a hydraulic power-plant at Morbegno, which delivers 7,500 horse-power.

Three-phase, 15-cycle current is generated at 20,000 volts and distributed to the line over an aerial transmission line. The high-tension lines are each composed of three copper wires of the following diameters:

Morbegno to Castione	7 mm.
Morbegno to Colico	8 mm.
Colico to Chiavenna	7 mm.
Colico to Lecco	7 mm.

There are 10 sub-stations along the lines, each of which contains a 300 K. V. A.-transformer, transforming the current from the transmission-line voltage of 20,000 volts to the 3,000 volts supplied the working conductors. Over each track are carried the working conductors consisting of two 8-millimeter overhead wires hanging from catenary messengers supported from span-wires between poles at the sides of the track; the third phase is carried by the bonded track return. 3,000 volts are used on the contact wires and the line is equipped with a sectionalizing block system which cuts the current off the block behind until the occupied block is clear. In addition, the sections of conductors above station platforms are so arranged that the current is turned off from them at all times, except when a train is passing.

Passenger trains are operated by motor cars hauling a variable number of trailers. Each motor car weighs about 53 tons and is capable of pulling a 250-ton passenger train at 40 miles per hour or a 400-ton freight train at 18 to 21 miles per hour. The original equipment of motor cars comprised 10. Freight is hauled by electric locomotives of approximately 700-horse-power capacity and weighing about 50 tons each. The locomotives are capable of hauling 400-ton freight trains at 20 miles per hour, or 500-ton freight trains on a level at 19 miles per hour. They are equipped with cascade control over the motors and with water rheostats so that an unlimited voltage control is afforded.

Since the electric traffic was inaugurated in September, 1902 (and it has since been in uninterrupted operation), they have had a few troubles, none of which were insuperable,— and these troubles were of the kind which may be regarded as inevitable when we put novel apparatus into service under new conditions. Since the opening of the line, the electrified section has been extended and a number of additions have been made to their rolling-stock. The drive-wheels of the later electric locomotives are fitted with side rods and the motors drive through cranks and connecting rods. This has been done, we believe, to prevent a difference in the diameter of the drive-wheels, as wear comes on, unbalancing the loads carried by individual motors. It is believed that these later locomotives are the ones which have been supplied to the Simplon Tunnel and with which trouble was experienced, although we have been unable to verify this.

Trains are run at a speed of 20 miles per hour, including stops, for the locals, and at 26 miles per hour, including stops, for express trains. Between stations, a maximum speed of 45 miles per hour is attained. There are 24 stations in the 67 miles of original electrification, of which 9 stations are express stops. The results are so far satisfactory that the Minister of Public Works expressed his approval of a 31-mile extension of the electrification southward from Lecco to Milan by way of Monza. The traffic on this extension, especially between Monza and Milan, is very much heavier than any north of Lecco. Another extension is being electrified, 26 miles long, between Lecco and Como.

The original 67-mile electrification of the Valtellina entailed an expenditure of $1,240,000. Of this, $500,000 was spent upon the hydraulic power-plant, which plant is three times the size needed for the original electrification, as it was made of sufficient capacity to take care of subsequent extensions. The rolling-stock cost $260,000 of the amount, and the line construction $340,000. The central-station machinery, in addition to the above-quoted $500,000, amounted to $140,000. The total cost, divided by the 67 miles of length, gives a cost of $18,500 per mile. It we reduce these costs, by charging against them only the proportion of power-house and machinery cost chargeable to equipment necessary to take care of power-demands for the initial electrification, the cost works out at less than $10,000 per mile of single track, everything included.

The following is quoted from Smith: "Nine months' working from January to September, 1903, showed an energy consumption of 2,198,000 kilowatt-hours for 48,100,000 ton-kilometers actual traffic, or 47.5 watt-hours per ton-kilometer."

The following is the power-station expenditure account for this period, reduced to costs per 1,000 ton-kilometers:

Working cost of power-station per 1,000 ton-kilometers in centesimi:

Staff	31.5
Oil	2.0
Taxes and insurance	4.15
Lighting and cleaning material	.43
Office utensils, etc	.62
Freight expenses	.24

Upkeep for	(a) Electrical machinery	1.17
	(b) Turbines and piping	1.15
	(c) Canals	1.57
	(d) Traveling and personal expenses	.62
	(e) Tools and apparatus	.46
	Total	44.3

That is, 0.97 centesimi per kilowatt-hour.

To this there is to be added the cost of the line working as given below. Cost of upkeep of line equipment and vehicles for 1,000 actual ton-kilometers in centesimi:

Staff:	(a) On the line	32.5
	(b) In repair shop	17.52
Oil		0.31
Telegraph fees, postage		1.03
Transformers		2.03
Upkeep of	(a) Vehicles	9.44
	(b) Primary and secondary line	2.89
	(c) Tools	1.12
	(d) Traveling	1.18
	(e) Lighting of stations and vehicles	1.24
	(f) Taxes and insurance	11.5
	(g) Accumulators	3.5
Repair shop		3.5
	Total	87.7
	Add	44.3
	Centesimi for 1,000 ton-kilometers	132.0

Or:
1.92 centesimi per kilowatt-hour for upkeep;
0.97 centesimi for power;

2.89 centesimi per kilowatt-hour total.
Or: 42 cents per 1,000 ton-miles for power.

Before the conversion, the cost of coal alone was 71 cents per 1,000 ton-miles, on this line.

According to Cserhati, the expenses for labor and material at the Morbegno power-plant from July 1, 1903, to June 30, 1904, were 21,553 lire, for generating 3,420,502 kilowatt-hours, or 0.118 cents per kilowatt-hour. The cost of maintenance and inspection of working conductors, poles, and transformer-stations was 329 lire per kilometer, or $104 per mile. The maintenance and repair of rolling-stock including electrical equipment and mechanical parts was 1.38 cents per locomotive mile. The total expense for tractive service including lubricating and cleaning material as well as labor, amounted on the average for the year, with partly steam-driven freight trains, to 62 cents per 1,000 ton-miles and with trains moved exclusively by electricity, to 54 cents. Comparing this with a similar Austrian road, a saving of 5.5% on total invested capital was thus secured.

Bela Valatin, quoted in the Street Railway Journal, August 5, 1905, states that on this road, in place of 686 train miles daily made under steam traction, under electrical traction 4 years later, 1242 daily train miles were made. 35,120 miles per electrical vehicle yearly was made, while the average steam locomotive mileage on the road was only 17,213. After three and one-half years, it had not been possible to measure any diminution in the section of the trolley wire. The rollers on bow collectors run 12,000 miles without repair. Most of the motor cars, at the time of this article, had run over 100,000 miles and it had not yet been necessary to change the bearings or remove the bushings. Only two or three breakdowns had occurred in the time and they were due to burning-out the bearings in one case through sand getting into them and, in a second, through the oil being shut off. The maintenance of overhead line and switches was only a very small part of the whole cost and was quite unimportant. In the year and a half preceding this paper there had been no occasion to repair the motor windings. He states that the working of telegraph wires has not been disturbed, although in fear of it the authorities made them adopt the most elaborate precautions at first. Only one man has been killed by the current in the entire 3½ years of operation, and he was killed in a sub-station through carelessness.

It is stated in the Street Railway Journal (April 1, 1905) that the repair gang for line maintenance is composed of five gangs of five men each, the necessity for this number of men being more to have a number on hand in times of emergency than that continual employment is afforded them. The total cost of maintenance of primary and secondary lines, the care, attendance, and maintenance of the sub-stations, and the patrolling of the line on this plan, is given at $102 per mile per annum. Slow-moving trains on the Valtellina take off 300 amperes from the trolley; at 40 miles per hour, 240 amperes; and at 62 miles per hour, 100 amperes. At the time of the Valtellina installation, the equipment proposed was more or less experimental. The equipment was made with guaraantee that should it not prove satisfactory, it would be removed free of cost and the road restored to its original condition. It was so much of a success that the equipment was accepted three months before the end of the probationary period.

In 1907, the following extensions were authorized by the Italian Parliament:

Milan-Monza-Lecco	30 miles
Usmate-Bergamo	15.6 miles
Calolzio-Ponte San Pietro	10.8 miles
Total	56.4 miles

MILAN-GALLARATE-VARESE RAILWAY

This line is operated by the Mediterranean Railway Company and is one of the two main lines in the Northern part of Italy. Its electrification was determined upon in order to test the feasibility of electrical working for the lines in northern Italy. This particular line was chosen because it was badly congested and it was necessary to get a greater movement over the road and to provide a more attractive service in order to suppress competition from certain local electric roads and secondary steam lines. As originally electrified, the line ran from Milan through Varese to Porto-Ceresio. A heavy local traffic was carried by the road. The lines electrified were as follows:

Milan to Gallarate	40 kilometers
Gallarate to Porto-Ceresio	33 kilometers
Gallarate to Laveno	31 kilometers
Gallarate to Arona	26 kilometers
Total	130 kilometers

or 81 miles of single track. The line between Milan and Gallarate is double-track; the rest is single. The maximum grade is 2% and grades of 1% to 1.2% are encountered in several places. The curvature is generally easy. There are 28 stations on the line, the average distance apart being 2.9 miles.

A direct-current third-rail installation has been adopted, current being supplied at 650 volts. Power is generated by a hydraulic power-plant of 8,800-horse-power capacity. When the installation was first made a temporary steam plant of 4,200-horse-power was installed. The savings effected have been larger, of course, with the cheaper hydraulic power than with the steam power. Three-phase 25-cycle current at 13,000 volts is generated and transmitted to five sub-stations. There are two transmission lines, the wires in one being 4 millimeters in diameter and those of the other 6 millimeters. The sub-stations are 6 to 7 miles apart. Each contains seven 180-kilowatt static transformers transforming the current to 420 volts, at which voltage it is led

Courtesy General Electric Co

West Jersey & Seashore Railroad — Motor Car Train at South Westville, N. J.—Standard Direct-Current Third-Rail Equipment.

to 500-kilowatt rotary converters delivering 650-volt direct current. A 90-pound third rail is used.

Trains were originally made up of one motor car and one trailer, but about 18 months after the inauguration of the electrification, the multiple-unit system was adopted in order to afford a greater traffic movement, and trains are now run with a variable number of motor cars and trailers, the usual trains containing about 6 cars. Motor cars are equipped with motors of a capacity of 640-horse-power and are fitted with double-end series parallel control. They are capable of making 56 miles per hour maximum. The mean speed from Milan to Gallarate is 27 miles an hour and over the whole line is 17 miles an hour. In 1905, 20 motor cars and 20 trailers were owned. This equipment has since been considerably increased. The service was inaugurated in November, 1901, on the Milan-Varese line and in June 1902, on the Varese-Porto Ceresio line.

The original estimates of the Royal Italian Commission for the electrification of the Milan-Varese line covering the electrification of 105.7 miles of track, was as follows:

Cost third-rail and accessories	$300,000
Bonding of third and track rails; insulation of third rail and conductors for primary current	160,000
Storage batteries, fixed machinery, and buildings	240,000
25 double-truck motor cars, exclusive of electrical equipment	150,000
Motors and accessories for above	190,000
5 electrical locomotives	60,000
Total	$1,100,000

Upon the electrification, according to Barbillon & Graffisch, the tariff was reduced 50% and the receipts thereon increased 125%, the daily train kilometers being increased from 580 under steam operation to 3,712 under electrical operation. During the first year's operation of this line, current reports stated that the car mileage under electric equipment had risen to 7,000,000 per annum against 3,000,000 under steam working and the passenger receipts from December 31, 1901, to August 31, 1902, amounted to 993,150 lire against 663,000 lire for the same period of the preceding year, notwithstanding a reduction in the fares. It is stated that the traffic on this line is now the most dense in Italy and that it would be impossible to obtain such a movement with steam; that notwithstanding the tariff reduction, the net returns upon capital have notably increased; and that the electrification has not only proven a technical success, but a commercial one. In view of the fact that the electrification of the systems throughout the whole of northern Italy, embracing the main line between Turin, Milan, Florence, and Venice, depends upon the success of this line and the Valtellina, the results obtained are extremely important.

The Italian Budget of 1907, contained a provision for the extension on these lines from

Gallarate to Laveno	32 kilometers
Gallarate to Arona	26 kilometers
Total	58 kilometers

SIMPLON TUNNEL

The Simplon Tunnel is 12.3 miles long and affords trunk-line connection between Milan, Italy, and Lucerne, Switzerland. Contracts were let for the electrical equipment of the tunnel late in 1905 to Brown, Boveri & Company, a section of the work being awarded on the Italian side to Ganz & Company. The three-phase system was adopted for the electrification although the contract for the electrical equipment contains a clause providing for the changing over to single-phase equipment, subsequently, if it is so desired. It is stated that the three-phase system was adopted temporarily because single-phase apparatus could not be delivered, promptly, in time for the opening of the tunnel. This seems likely, since a portion of the new equipment for the Valtellina was sent to the Simplon Tunnel when first opened.

The power-plants are located at Brieg in Switzerland and Iselle in Italy. 15-cycle current is generated and delivered to the trolley wires at 1,300 volts. The working conductors are carried 15 feet 9 inches above the rails in the tunnel and 17 feet in the open. They are suspended from span-wires between iron poles (in the open) every 82 feet. Both passenger and freight trains will be hauled through the tunnel by electric locomotives.

The locomotives ordered for the tunnel will have motors designed for two speeds of the locomotive, 20 and 40 miles per hour, respectively. The estimated weight of locomotives is 62 tons, 42 tons being on the drivers. Draw-bar pull at the lower speed is 1,320 pounds and at the higher, 6,650 pounds. The maximum weights of passenger trains are 400 tons, and of freight trains 500 tons. The Italian Budget for 1907, provided for an extension of the electrification between Domodossola and Iselle, 12 miles. Large storage yards are provided at each end of the tunnel, one of which contains 17 parallel tracks.

BREMBANA VALLEY

The Bergamo and Brembana Valley railway, a single-phase light mountain road, is not an electrification in the true sense of the word, but is an example of the trend of electrical traction, in that its construction was considered as a steam railroad, but it was decided to build it as an electrical railroad outright,— as the physical conditions of the road and the availability of cheap water power made it more advantageous to so construct it.

The road extends between Bergamo and Giovanno Branco, 16 miles. The maximum grade is 2.4% and there are 17 tunnels along the route.

A single-phase system has been installed. The power-house contains three 1,500-kilowatt hydraulic units. The working conductor is carried mostly over a single-pole bracket construction, although there is some bridge work. Poles are spaced 115 feet on tangents. The working conductor is suspended from a single catenary messenger and is of 8 millimeters diameter. A No. 0 feeder parallels the line.

Trains are hauled by geared locomotives, of which there are five in use, each equipped with four 75-horse-power, single-phase motors. Current is collected by means of a pantagraph pneumatically operated. The locomotives are fitted for multiple-unit working. The average train weighs 90 metric tons. Locomotives have an acceleration of 1.5 miles per hour per second, and have each hauled 120 tons (metric) trailing load on a 2% grade at 11 miles per hour.

ROME-CIVITA-CASTELLANA RAILWAY

This road is similar to the preceding, having been built as an electrical road rather than a steam road into new territory, because the conditions were favorable for electrification. The road is 32 miles long. Passenger trains are made up of motor cars and trailers. Freight trains are hauled by electric locomotives. A single-phase system was adopted.

FURTHER ITALIAN ELECTRIFICATION PROJECTS

In 1907, the Italian Parliament appropriated 50,000,000 lire, ($10,000,000) for electrifying the following trunk line divisions of the state railways.

1. Pontedecimo-Busalla.................... 11 kilometers
2. Savona–S. Giuseppe.................... 21 kilometers
3. Bardonechia-Modena.................... 7 kilometers
4. Milan-Monza-Lecco...................... 51 kilometers
5. Usmate-Bergano.......................... 26 kilometers

6.	Calolzio-Ponte San Pietro	18 kilometers
7.	Gallarate-Arona	26 kilometers
8.	Gallarate-Laveno	32 kilometers
9.	Domodossola-Iselle	19 kilometers
10.	Pistora-Porreta	40 kilometers
11.	Naples-Torre-Annunziata-Salerno	54 kilometers
12.	Torre-Annunziata-Castellamare	6 kilometers

This makes 193 miles in all. The work is to begin not later than 1911. Nos. 1 and 2 are portions of the Genoa-Milan and Savona-Turin trunk lines. No. 3 is a portion of the Paris-Turin line of which the Mont Cenis tunnel forms a part. No. 4 is an extension and Nos. 5 and 6 are branches of the Valtellina covering connections with Bergano. Nos. 7 and 8 are extensions of the Milan-Gallarate-Porto Ceresio line. No. 9 is a part of the trunk line between Milan and is an extension of the Simplon Tunnel. 10 is an extension of the trunk line between Milan and Florence and Rome, constituting the main line through the Apennines. Nos. 11 and 12 are extensions from the connection between Naples and the Sorrentine Peninsula.

Nos. 4, 5, 6, and 9 will probably be operated on the three-phase system since the lines which they join already have this system installed. Nos. 7 and 8, for a similar reason, will be installed with a third-rail, direct-current installation. For No. 1, it is said that the contract has already been given to the Westinghouse Company, for three-phase equipment. It is probable that Nos. 2, 3, and 10 will also be three-phase. There is a possibility of Nos. 11 and 12 being single-phase.

While Nos. 1, 2, 3, and 10 are comparatively short branches of trunk lines, they have very severe operating conditions. These are all mountain divisions with numerous curves, heavy grades, and long tunnels. Owing to constantly increasing weights, trains have difficulty in holding their schedules. In addition, many are single-track lines, which has aggravated the delays. The smoke nuisance has been a factor in determining the electrification, particularly in the case of the Mont Cenis Tunnel.

Electrification is also considered desirable for the lines running from the harbors of Genoa and Savona as they carry a large through business to other countries and also the major part of the industrial material, including fuel, used in the heavily populated districts of northern Italy. The rapid growth of industries in Lombardy and Piedmont has taxed these railroads to such an extent that they have had to handle the extra business by increasing the train loads and the schedules. They have not always been able to cope with the situation. Fuel famines have resulted, forcing industrial plants to shut down occasionally. The Pontedecimo-Busalla is really a freight line. The more important passenger trains are carried on a parallel line through Ronca Tunnel. It is intended to handle freights of 400 tons trailing load up grade and heavier trains down grade. Freight trains will be operated by two electric locomotives, one at the head and the other at the other end of the train. Up-grade trains will be run on a 15-minute schedule at first, later; on a 10-minute schedule. Power for this line will be generated by a 7,500-kilowatt steam-turbine station at Genoa, and transmitted to three sub-stations. It is contemplated operating the trains 18 hours a day.

SWITZERLAND

As early as 1903, the Swiss government had a report prepared on the advisability of adopting electric traction on a part of the state railways, and application was made to the government by a commercial company for permission to use electricity on a trial road 12 miles long.

In 1904 a Commission was formed for the study of electric traction on the Swiss railroads. It was composed of representatives of (1) administrative officials of the railroad companies; (2) the five principal Swiss electric construction firms; and (3) of the Swiss Association of Electrical Engineers and of the Association des Centrales Suisses. The principal lines of the committee's work were (1) a general study of the applicability of electric traction, taking into account the various Swiss lines, from the lines of secondary interest to principal lines; (2) a comparative study of the various electrical systems from both a financial and a technical point of view; (3) a study of various water powers available and their costs of development, the cost of energy available from existent installations and from new installations; (4) the establishment of plans for development, for construction and for exploitation of some typical cases, basing them upon systems found to be most appropriate; (5) the establishment of standard types of construction details,— line construction, feeders, equipment, motors, locomotives, etc.

The report was brought in in 1906, and experiments on the electrification of Swiss roads have been in progress since.

BURGDORF-THUN RAILWAY

This is a small road in northeastern Switzerland formerly operated by steam, but electrified in 1899, and opened to traffic under electrical working in July of that year. It is a secondary road, but it is of considerable importance because of the international communication it affords. The road is 25 miles long and has 15 stations along its route.

A three-phase system has been installed. Current is generated at 16,000 volts and carried over a transmission line to 14 sub-stations located in the buildings of the passenger stations. The transmission line is carried by three wires of 5 millimeters diameter. Each sub-station contains a static transformer of 450-kilowatt capacity, which drops the voltage to 750 at which pressure it is supplied to two working conductors over each track. The third phase is carried by the bonded rail.

Motor cars hauling one or more trailers are used for passenger traffic and operate at a speed of about 22 miles per hour, including stops. Electric locomotives of 300 horse-power each, are provided for freight service.

The cost of this electrification was as follows:

38 kilometers of high-tension circuits including branch circuits	$28,000
Trolley line and track return, including 6 kilometers of double track at switches, feeders, poles, insulators, switches, lightning protectors and erection	70,000
14 450-kilowatt transformer-houses	34,000
Station lighting and repair shop	4,000
Electric rolling stock equipment: 6 motor cars, 2 locomotives; light and heating equipment	47,000
Reserve parts	6,000
Total	$187,000

According to Barbillon and Graffisch, the road is poorly operated. Only 17 trains per day each way are run and it is said that a mistake has been made in the electrification of this road, as the traffic density is not sufficient to support the investment.

FRIBOURG-MORAT RAILWAY

This road is 13.3 miles long, extends from Fribourg to Morat, near Neufchatel and was formerly operated by steam. It was electrified about 7 years ago. It possesses a maximum grade of 3%. It was electrified because cheap water power was available and because the cost of operating by steam was high on account of the heavy grades.

The usual train consists of 1 motor car and 4 trailers. 70-ton trains can be hauled at a speed of 22 miles per hour. Freight is handled by electricity. The operation is stated to be most satisfactory from an electrical and a mechanical standpoint.

MONTREUX-OBERLAND-BERNOIS RAILWAY

This electric road, filling the place of a steam road, was built in order to afford connection between certain scenic points in Switzerland. It is 24 miles long.

Power is generated by a hydraulic power-plant of 6,000-horse-power capacity, which generates 50-cycle three-phase current at 8,000 volts. This is transmitted over a transmission line of 6-millimeter wires, to 4 sub-stations, 9, 10, and 11 miles apart, respectively, where, by motor generator sets, it is transformed to direct current and delivered to the trolley line, a feeder tying into the line every 600 feet.

The original passenger trains were hauled by electric locomotives, but these were given up and motor cars hauling trailers were substituted for passenger traffic. Each motor car is equipped with four 65-horse-power motors and the ordinary train is composed of one motor car and one trailer. The current is collected by a bow collector. Electric locomotives are used for freight haulage.

SEEBACH-WETTINGEN RAILWAY

This is a part of the Swiss national railway system and was chosen, in 1904, for electrification in order to test the advisability of electrifying certain branch lines of the Swiss national railway system. The line is about 15 miles long and is double-tracked. In 1904, a contract was let to the Oerlikon company for the electrification of about one-third of the track by the Huber system. This is a single-phase system, the most notable feature of which is the line construction. The working conductor is carried on the top of insulators by clips, in such a manner that the collector slides along the upper surface of the wire on ordinary installation. The collector is a curved rod which is pressed against the wire. In addition to the line construction we have indicated, devices have been worked out which permit the installation of the conductor in almost any position, such as along the side of a tunnel, the collector altering its position to take current from such difficult positions without sparking. It is perhaps the most flexible arrangement of working conductor and collecting apparatus yet devised, viewing it from the point of the necessity of carrying the conductor through contracted spaces and under low clearances.

Trains weighing 150 to 200 tons have been hauled over the line by electric locomotives, for the purposes of experiment. As the installation has been made merely for the purpose of proving the engineering feasibility of electrification, a partial steam service has been retained on the line,— about 4 trains each way per day being run by electricity.

The estimated cost of the line equipment for the early construction, including poles, contact wires, section switches, laps at sections and stations, and accessories of all kinds complete, erected, and in working order was $1,500 per kilometer, or $2,400 per mile.

The line from Seebach to Affoltern, 2.4 miles in length, was electrified first. At present the line from Seebach to Regensdorf, 4 miles, has been equiped with Oerlikon equipment and 8 miles of route has been equipped with Siemens-Schukert equipment, the latter installing an overhead, single-messenger catenary construction supported from steel bridges.

Two Oerlikon locomotives and one Siemens-Schukert are in use at present. One of the locomotives is equipped with the Ward-Leonard system.

15,000 volts are now carried on the working conductors, transformed to 750 volts on the locomotive.

VALLE–MAGGIA RAILWAY

This is a mountain road 17 miles long with a maximum grade of 3.3% connecting Locarno and Bignasco. The Oerlikon company was given the contract to electrify this road in 1906, with the single-phase system, because of its success with the Seebach-Wettingen line.

Power is generated by a hydraulic plant. A line voltage of 5,000 is used. Motor cars hauling trailers are used for carrying both passengers and freight.

ST. GOTHARD RAILWAY

Estimates for the electrification of this tunnel were made by the Oerlikon company in 1904, with a view to reducing the working expenses. The fuel cost is very high, being about 20 cents per train mile. It was estimated that the expense could be reduced to 14.5 cents per train mile. This figure includes interest on reserve fund as well as maintenance expenses of the system. The Oerlikon engineers estimated that it would cost about $1,000,000 to establish electric traction between Erstfeld and Bellinzona. A saving under electrification of 10% on the total capital investment in the tunnel and the electrification, it was believed, would be effected, or of 30% on the electrification.

L'Electricita published an announcement in November, 1906, that work upon the plan for the electrification had been ordered begun and that the section of the road from Zurich to Lucerne would be constructed as an experiment, but this work has not yet been carried out.

STANSSTADT–ENGELBURG

On this electrically-equipped Swiss mountain road, 14 miles long, a three-phase system is installed, current being generated by water power. Considerable freight traffic is handled by electricity, in addition to passenger traffic.

FRANCE

PARIS–ORLEANS RAILWAY

This is an electrification of the Paris-Orleans railway into their Paris terminal. The Paris-Orleans is a very important railway system. It extends to the Spanish frontier and furnishes the most important communication to Toulouse and Bordeaux on the south and reaches Brest on the west. A new depot was built near the center of Paris to which access was had from their former station by means of a tunnel 2.5 miles long. The electrification was determined upon largely in order to obviate the production of smoke in this tunnel. Electric traction on this terminal section was inaugurated in June, 1900. All trains, except fast, through, limited, trains are hauled into the terminal by electricity. These latter go through the tunnel by steam. Freight trains are hauled over the line by steam, as the freight terminal is reached before the tunnel section; the freight yards being at Austerlitz, the former terminal.

The suburban traffic of this railroad was not large prior to the electrification, as the old terminal (Austerlitz) was too far from the center of the city. After the inauguration of the new terminal at the Quai d'Orsay, the desirability of building up the suburban traffic became apparent,— (1) because of the possible opportunities of having this traffic add a profit and (2) because of the desirability of extending the scope of their electrification beyond the short section originally electrified, in order to permit a more intensive working of the existent plant and in order to afford a more even demand upon the electrical equipment. In 1903, the extension of the zone to take in the electrical working of suburban traffic was decided upon and the electrification was extended over 12 route miles of double track, with a number of switches and sidings. This extension is from Austerlitz to Juvisy, which latter is a junction point with the Grande Ceinture, or Belt Railway, encircling Paris; the extension also connecting with the Paris, Lyons & Mediterranean railway. New passenger stations for suburban traffic have been built and a frequent and fast suburban service has been put on. At the same time, instead of attaching the electric locomotives to the trains at Austerlitz, they are attached at Juvisy. Through trains are hauled by electric locomotives and the suburban traffic is handled by multiple-unit trains. Electric locomotives haul from 150 to 200 trains per day, weighing about 150 tons on an average and 350 tons at a maximum. The terminal station comprises 16 tracks. Between Juvisy and Quai d'Orsay, 14 miles, there are 8 stops. Suburban trains which make all stops, make this trip in 34 to 38 minutes, stopping one-half to one minute at each station, or an average speed of 28.5 miles per hour. Trains making only two stops, make the trip in 26 minutes, and their average speed is about 31 miles per hour. Speed is limited in the tunnel on account of curves. The average daily mileage is 124 miles for electric locomotives and 155 miles for motor cars.

The power-station is at Ivry and contains 3 four-cylinder triple-expansion Corliss engines direct connected to 1,000-kilowatt alternators, or a total of 3,000 kilowatts in the original installation. Three-phase 25-cycle 5,500-volt current is generated and carried to three sub-stations where it is converted into 650-volt direct current and delivered to the working conductors. A third-rail system is installed. Conductors are 52-pound T-rail with a flat bar on each side, the bars weighing 26 pounds per yard. The rail is carried on blocks of creosoted wood on the ends of the ties and is unprotected except at stations. The usual interruption of conductor rails at crossings and station platforms occurs. Sectionalizing switches are arranged to be operated from a distance by the operators in the interlocking and signal towers.

There are 11 electric locomotives each having a pair of trucks with a motor on each axle. The engines run light at 62 miles per hour on a level, or 43.5 miles per hour when hauling a 200-ton train, or can haul a 300-ton train the 3.8 miles on 1.2% grade between Austerlitz and Quai d'Orsay, in 7 minutes. The later locomotives are built with a car body, the electrical apparatus being contained in a cab at one end and the bulk of the locomotive given over to a baggage compartment. Only one man is carried on the locomotive. Motor cars are built for a speed of 50 miles per hour. The earlier ones are fitted with four 80-horse-power motors each, or 320-horse-power total. The later ones each have four 125-horse-power geared motors. They are fitted with multiple-unit double-end control. A typical train is made up of two motor cars with five to seven trailers between. This arrangement is adopted to avoid terminal switching. Such a train weighs 175 tons empty and has seats for 520 passengers. Suburban service has been in regular operation since July 1, 1904, when 70 to 80 trains each way daily were put on, this number having been increased since.

It is stated that an extension of the suburban service of 8 miles to Bretigny is contemplated.

The following figures are extracted from a paper by Dubois, read before the International Railway Congress, in 1905:

The construction costs for traction alone were approximately:	
Power stations, 2,000 kilowatt	$413,000
Transmission system, 22.18 miles	103,000
Sub-stations (3)	215,000
Working conductors 37.29 miles	463,000
Rolling stock (11 locomotives, 5 motor cars)	280,000
Miscellaneous	16,000
Total	$1,490,000

The results of operation on the Austerlitz-Quai d'Orsay section, in 1903, were: an average number of trains per day of 150, covering the distance (2.5 miles) in 7 minutes for express trains and 9 minutes for locals. Average speed between stops 28.3 miles per hour express, and 16.5 miles per hour for locals. Maximum speed 31 miles per hour.

Mileage of Locomotives:

Hauling trains	139,856
Not hauling trains or switching	30,328
Total	170,184
Total miles per locomotive	15,115
Total ton-mileage, not including locomotive	23,601,505
Energy consumed at switchboard 1,367,080 kilowatt-hours; total ton-mileage or 58.1 watt-hours per ton-mile, or 97.73 per ton-mile useful mileage.	
The average cost per train mile was	$0.2555
Or	.165374
per train kilometer, made up as follows:	
Depot charges	$0.003312
Train staff	.062304
Electric energy	.081810
Lubrication	.001944
Various expenses	.001004
Maintenance and repairs	.015000
Total	$0.165374

The cost of power, which is the largest item, was as follows at power-station:

Staff	$0.0025828
Fuel	.0044384
Lubrication	.0003376
Miscellaneous	.0005522
Maintenance and repair	.0001468
Total	$0.0080578

Cost per kilowatt-hour at sub-station terminals:

Energy .080578÷.782=	$0.0103040
Staff	.0014746
Lubrication and miscellaneous	.0000290
Maintenance and repairs including transmission system	.0005522
General expenses	.0001468
Total	$0.0134706

The cost of labor is said to be high, as the service is really a switching service. Thus the average yearly mileage for this year of a locomotive car is only 11,345 miles.

Mr. Dubois stated that the maintenance of the electric plant is very small; that the cost of working is higher than the cost of steam traction on the whole Orleans system, but that the special service, which is really a switching service, should be taken into consideration. He predicted that when the service from Paris to Juvisy should be started, this cost would be less, as a greater mileage of equipment would be obtained and the power station would be working nearer its designed capacity. This prediction came true, as after the extension of electric traction to suburban service it was announced that the annual kilometric run of electric trains had increased from 225,000 to more than 500,000 and that the cost of traction per train kilometer had decreased to about 60 centimes,— that is, a reduction from 16.54 cents to 11.58 cents.

PARIS-VERSAILLES RAILWAY

The Chemins de Fer de l'Ouest operates a suburban service between Paris and Versailles, a distance of 10.94 miles. It was formerly operated by steam, but was electrified in 1901, electrical service being inaugurated in July of that year. Most of the road follows the old steam road with the exception that the electrified section branches off at Mollineux, about 400 yards outside the old fortifications of Paris and rejoins at Viroflay the old line from Versailles to Mont Parnasse, traversing the wood of Meudon in a tunnel about 3,700 yards long. The reason for its electrification was stated by M. Sabouret of the French Western railway to be the existence of the terminal station at Paris, which is partially underground and of this tunnel, with a continuous up grade of .8%, it being necessary to avoid making smoke in both places.

A third-rail direct-current equipment has been installed. The power-house at Mollineux generates three-phase 25-cycle 5,000-volt current which is carried in 3-conductor cables, in conduits in the ground, to three sub-stations located at Champs de Mars, Meudon, and Viroflay, respectively. Each sub-station contains a 30-kilowatt rotary converter which converts the current into 550-volt direct current which is fed into the third rails. The third rail is carried on paraffined wood insulators spiked down to the ties every three or four yards. Feeders are connected into the third rail every kilometer. Sectionalizing switches are installed at convenient intervals. The bonded track is used as a return.

Electric locomotives were originally used in this service but they have been replaced almost exclusively by motor cars, standard multiple-unit equipment being now used. A service of about 5 trains per hour each way was originally installed. The following operating figures are selected from a paper read by Mr. Paul Dubois before the International Railway Congress in 1905:

Total electric mileage 1903, 228,153,— 188,230 of which was by electric locomotives. Total ton miles, 19,301,192. Power consumption, 93 watt-hours per ton mile at switch-board, or 66 at train, the weight of the locomotive not being counted.

Cost per kilowatt-hour at station, maintenance of high tension cables included	$0.002852
Staff	.007440
Lubrication, water, maintenance and repairs	.000744
General expenses	.001364
Total	$0.012400
and at sub-stations, per kilowatt-hour	.0240
Coal costs $4.00 per ton. Coal consumption per kilowatt-hour	3.738 pounds

Cost of traction per train mile was as follows:

Train staff and motormen	$0.03244
Electrical energy	.16686
Lubrication and miscellaneous	.00588
Maintenance and repair of locomotives and motor cars	.05006

Maintenance and repair of working conductors at $233 per mile	.02410
Total per train mile	$0.27934

The average annual mileage is 19,260 per locomotive and 33,210 per motor car, including switching and running empty.

FAYET-CHAMOUNIX RAILWAY

This road is owned by the Paris, Lyons & Mediterranean System. It is a scenic branch of road into the French Alps, and because of its steep grades it was never operated by steam, but was electrically equipped from the first. It is, however, a portion of a standard steam railroad system. The line is about 11 miles long.

A standard direct-current third-rail construction has been adopted. Power is generated at a hydraulic plant of 2,000-horse-power capacity.

Trains of multiple-unit cars are used, four to five coaches being run to a train.

The line was put into operation in 1902. It was not intended to operate during the winter months, the company being authorized by its concession to suspend its operation during the winter months and to charge fares double those obtaining on the main lines of this road. The results of its working were so satisfactory, however, that it is now operated the year round, except when heavy falls of snow prevent. Eight trains each way per day are run.

The train mileage in 1903 was 36,040 miles. Ton mileage 4,109,728. The watt-hour consumption (over a heavy grade) is 146 per ton mile. Power costs 0.8 cents per kilowatt-hour. The total cost of operation is $0.6026 per train mile.

MOSELHUTTE RAILWAY

This was a steam road 8.7 miles long connecting the Moselhutte Iron Mines in Lorraine with some blast furnaces owned by the same company at Ste. Marie. A 3% grade is encountered in both directions. Steam locomotives double-headed were only able to haul 200 to 300 ton trains and make the round trip in two hours. About 2,600 tons of freight per day were hauled by steam. Because of a desire to get greater capacity out of the road, its electrification was decided upon and contracts let to the Siemens-Schukert Works.

Three-phase power is generated at 5,700 volts and the current transmitted to a sub-station at each end of the line. Sub-stations deliver their current to the line at 2,000 volts direct current. A trolley line construction is adopted, two overhead wires 5 inches apart being carried above each track.

Three locomotives have been supplied, each weighing 55 tons. The locomotives are each equipped with four 160 horse-power 2,000 volt motors. Current is taken from the wires by double-jointed bow collectors. The traffic over the line is exclusively freight.

LA MURE RAILWAY

The Chemins de Fer de la Mure in the Grenoble region, in southeastern France, had a heavy freight traffic between St. Georges de Commiers and La Mure, 20 miles apart, which they had great difficulty in handling under steam. The road is single track, possesses a maximum grade of 2¾% nearly the whole way, has a minimum curve radius of 100 yards and has a traffic mostly of freight and coal, with a small passenger service. A revenue of $7,000 per kilometer, or $11,650 per mile was received from the road and it became impossible to move the traffic by steam. The steam locomotives were of 37 and 41 tons weight respectively and had difficulty in hauling trains with 12 or 14 empty cars up this grade. The traffic, in general, consists in running empty coal cars up the grade and loaded ones down.

Convenient water-power was available. Electrification was introduced in 1903, and put into working in August of that year, the exploitation being done directly by the French Government.

Power is generated at a hydraulic station. A span wire, overhead trolley construction is adopted, two wires being carried over each track, one being supplied with 1,200-volt positive current and the other with 1,200-volt negative, giving a potential difference of 2,400 volts, the bonded track serving as a neutral third wire. The working conductors are 12 millmeters in diameter, feeder wires 9 millimeters.

Electric locomotives weighing 50 tons, equipped with 550-horsepower motors, capable of hauling 20 cars of a gross weight of 110 tons up the grade at 13 miles per hour and of handling a 330-ton train down grade are used.

According to Dubois, the up-hill energy consumption is 219 watthours per ton-mile. Adding the consumption for other purposes makes an expenditure of about 125 kilowatt-hours for running up a train of 20 empty cars (110 tons) and running it down loaded. At one cent per kilowatt-hour, this entails an expenditure of $1.25 against a former expenditure of $1.88 for coal for the same work, coal costing $5.60 per ton.

PRUSSIA

Prussian Government experiments date back about 7 years. In 1900, some preliminary high speeds tests were made by Siemens and Halske, following which, a society for the study of electric traction at high speeds for steam roads was formed at Berlin by representatives of (a) several important banking houses; (b) industrial houses; (c) the firms of Krupp and Borsig; (d) and the two strongest German electrical manufacturing companies, namely Siemens and Halske, and "L'Allgemeine Electrictats Gesellschaft." This association had the assistance of the German Government. Under its auspices were conducted some very remarkable high-speed trials which had the demonstration of the practicability of very high speeds under electrical traction as their object. A 14-mile stretch of track was secured with curves of 1,000 yards radius and relaid with heavy steel rails. In 1901 and 1902 a series of tests were carried out on this track, known as the Berlin-Zossen tests. A three-phase equipment was provided, current being delivered at 10,000 volts, motor voltages of 1,850 volts being used. Both electric motor cars hauling trailers and electric locomotives were used in the tests. In them, the remarkable speed of 130 miles per hour was attained. After this, the electrification of certain roads from Berlin and from Hamburg was carried out in 1901 to 1904, and governmental research has been made as to the feasibility of electrifying certain of the government railways, particular attention being given to those lines which would show a big saving in fuel consumption, as there are large deposits of lignite and of the poorer grades of coal available in Germany which could be utilized in the boilers of an electrical power-plant and which are not well adapted to consumption on railroads. These government investigations have resulted in definite proposals to electrify certain trunk lines in the fuel district.

BERLIN-WANNSSEE RAILWAY

The Berlin-Wannssee Railway is a part of the Prussian state railways, forming a portion of the Berlin-Potsdam line. It is a little over 7 miles long and is a double-track road running from Berlin to the suburbs. The electrification was begun in 1901, 2 motor cars and 8 trailers being tried in service for a year in competition with steam traffic on the line. A 650-volt direct-current equipment was provided, a third-rail construction being installed. After the system had shown its serviceability, the complete electrification of the road was carried out.

At present, 10-car trains are run, weighing 193 to 210 tons. The first and last cars of these trains are motor cars. The distance from Berlin to Potsdam, 7½ miles, is made in 20 minutes. A maximum speed of 55 miles per hour is made.

SPINDLERSFELD-NIEDERSCHOENWEIDE RAILWAY

This road is a part of the Government steam roads and was formerly operated by steam. It is in the vicinity of Berlin. It has been electrified with a single-phase system for experimental purposes. It is only about 1¼ miles long. The electrification was carried out in 1903 and the service opened to the public in June of that year. After a year's probation, it was taken over by the Government.

The line construction is a catenary suspension from a single messenger. In certain parts, a double catenary is used. Only one train is in use, comprising two motor cars and three trailers. It makes about 40 round trips per day. It is interesting to note that no reserve equipment is carried. When repairs are necessary to a motor coach, a shorter train carrying only one motor car is run. So far, little trouble has been experienced.

HAMBURG-BLANKENESE-OHLSDORF RAILWAY

This line is a portion of the Royal Prussian railways and was changed over to electrical working on the single-phase system in 1905. Single-phase current at 6,300 volts is carried on the working conductor. Single-messenger catenary suspension line work is installed. A working conductor is suspended beneath the carrying conductor, similar to the new construction on the New Haven. On the city sections of the line a low voltage is adopted and the low-tension conductor is carried at a lesser height from the track than the high-tension wires in the country sections. The high-tension collectors have sliding contacts of aluminum, while the low-tension collectors are of the roller type. The low-tension collectors are short and can never spring high enough to come into contact with the high-tension wire. When the overhead collectors change from the proper height for the high-tension wires to the proper height for the low-tension wires, a commutating switch which is connected pneumatically and electrically with the collectors changes the connection of the motors from the transformer to the trolley wires direct.

Two-car trains are run at a maximum speed of 36 miles per hour under a three-minute headway.

STADT UND RINGBAHN

In the summer of 1907, Dr. W. Reichel, of the Berlin Technical High School, submitted estimates to the Prussian Government for the electrification of the Stadt Bahn, a connecting steam suburban line through Berlin, and the Ring Bahn, a belt line around the city. He estimated that an expenditure of $20,000,000 would suffice for the electrification of 120 miles of this road. Following the decision of the Prussian Government to electrify these roads, a commission came to the United States in August, 1907, to study electrical transmission systems. According to Berlin papers, the plan decided upon was made public by Minister Breittenbach of the Railway Department. The plan is to divide the system of 366 miles into two sections, one to be electrified by 1913 and the other to be electrified by 1920.

The single-phase system with a trolley voltage of 10,000 volts will probably be used.

EXPERIMENTAL TRACK

The Prussian Government has in use this year (1908) a circular track of 1.08 miles at Oranienburg, about 31 miles north of Berlin, equipped for carrying out experiments with electric high-speed construction.

COLOGNE-BONN RAILWAY

This line is a former steam line 17.6 miles long, extending between Cologne and Bonn. A direct-current catenary construction with two trolley wires over each track is employed, 990-volts direct-current being supplied outside the cities. Within the city limits of Cologne and Bonn a trolley voltage of 500 volts is adopted, current being bought from local companies. The 990-volt current for the country section is supplied from a steam power-station at the center of the line. Freight is handled by steam on this line.

EIFELBAHN

Announcements were made in October, 1907, that the electrification of the Eifelbahn had been determined upon. This is a road which extends from Cologne to Treves, with 112 miles of double track. It runs through a bleak, mountainous, rugged, volcanic plateau seamed with gorges and situated between the rivers Rhine, Moselle, and Roer. Most of the road is up or down hill. It starts at Cologne at an elevation of 120 feet, crosses the watershed at an elevation of 1,815 feet, 52 miles from Cologne, and drops to 435 feet at Treves. It runs through an important coal, iron, and smelter district. Another road running up the Rhine is in competition with it, but the road is overcrowded.

This road is so hilly that only small trains can be pushed over it, while it is estimated that with single-phase locomotives, 1000-ton trains can be handled,—besides which, there would be great economy, particularly since one of the power-stations can be located on the lignite beds near Cologne and that fuel can be used.

A cheap trolley construction is contemplated, carrying 10,000 volts on the line, the power to be transmitted by a 30,000-volt transmission line. Late reports are to the effect that the electrification of this road has been vetoed by the War Department, on account of its being near the frontier, its electrification making it more vulnerable to attack in time of foreign invasion.

LEIPSIC-HALLE RAILWAY

The Prussian Government authorities are at present working on a plan for the electrification of the Leipsic-Bitterfeld-Magdeburg and the Leipsic-Halle, both of which are operated from Halle. Between Leipsic and Halle are extensive deposits of coal and it is contemplated locating the power-plant in the center of the coal district and supplying single-phase current at 10,000 volts to the railroad. The Leipsic-Bitterfeld-Magdeburg line is 79 miles long and the Leipsic-Halle line 23 miles long. Preliminary investigations have been made by the management, but they are having the Halle officials check them, according to press reports.

SAXONY

DRESDEN-MICHTEN KOETSCHENBRODA

This was a steam road belonging to the Royal Saxon railways and doing practically a street railway traffic. In 1899, the Saxon Government turned it into a standard trolley road with an auxiliary steam service.

BAVARIA

Early in 1908, the Bavarian Government announced its intention to electrify a part of the state railway system. Cheap water-power is available and it is proposed to make use of it. A few branch lines are first to be electrified as a trial and if it is successful, the electrification is to be extended. Important military authorities will not give consent yet to electrifying the main line.

Two projects are announced. The line from Berchtesgaden to Reichenhall and Salzburg, a distance of 40 kilometers, will be electrified. Power is to be delivered from the Saalach, where a 5,000-horse-power station to cost $375,000, will be constructed. The second line is between Garmisch and Griesen, 9 miles. A 20,000-horse-power station will be built, to cost $315,000, and $215,000 will be spent upon line equipment.

Twelve locomotives are stated to be an order, to cost $180,000.

The Salzburg-Berchtesgaden line has already been converted. This is owned jointly by the Bavarian Government and the Salzburg Tramway Company of Austria. A high-tension direct-current system has been adopted, the voltage on the Bavarian section being 900 and that on the Austrian section 750. The freight business is still carried by steam locomotives.

The Electric Railway Journal (June 30, 1908) announced that the Bavarian Government has decided to introduce electric traction on three railway lines near the Austrian frontier. In an official report just issued on this project, the cost of equipping the power-line is stated to be estimated at $442,500, and the power required 1,700,000 kilowatt-hours annually. The cost of the entire project is estimated at $5,500,000. It is further stated that an international competition for designs will be held.

AUSTRIA

Electrification in Austria has been largely experimental, although some small railways have been electrified and an investigation is being made into the electrification of the mountain division of the main line road between Paris and Vienna.

In 1902, a three-phase high-tension road at the Wollersdorf Arsenal, one mile long, was equipped and put into operation for experimental purposes by the Austrian War Department. On this line 3,000 volts was carried on the trolley. An electric locomotive was used for haulage. The voltage at the motors was 300 volts.

VIENNA STADT BAHN

This is a suburban road out of Vienna, still operating under steam over a double-track line 17.2 miles long, 22% of which is in tunnels. Trains of 130-tons weight are hauled. As an experiment, the Krizik Works were authorized in 1905 to electrify a 1¼-mile length from the Custom House to Praterstern. The Praterstern section was chosen because it is the most difficult on the road. The average distance between stations on this section is 2,050 feet, while on the whole road the average distance is 3,115 feet. This section has a 2% grade and a heavy curve.

A three-wire direct-current system is employed, two wires carrying 1,500 volts negative and positive respectively, the bonded track taking the place of the neutral wire. Center pole bracket construction is adopted. Stub tracks and switches have only one wire carried over them. This allows half speed and prevents complicated overhead work, half speed being all that is required at such points. Hauling is done with electric locomotives, each equipped with four 750-volt 200-horse-power motors, two being always in series. The locomotive weighs 29 tons and is equipped with two pantographs, a separate one collecting current from each wire. No sub-stations are employed. It is believed that by the equipment of this road electrically, the headway between trains can be reduced from 3 to 2.5 minutes during the rush hours. There is a power consumption of 77 watt-hours per ton-mile.

VIENNA-BADEN RAILWAY

This is a line 17 miles long, partly a connection of street car lines and of steam suburban lines, the conversion of which into a single-phase electrical line was decided upon in 1905. This work has now been carried out.

Three-car trains are run, each consisting of 1 motor car and 2 trailers. The motor cars are each equipped with four 40-horse-power motors. Current is taken off by a double pantograph collector.

TABOR & BECHYNE

This is an electrification of a road in Bohemia (opened on June 22, 1903) with a 1,400-volt direct-current equipment similar to that of the La Mure road in France. The road does principally a passenger business.

BUDAPEST ROADS

On February 28, 1905, the Royal Hungarian Minister of Trade authorized the electrification of the following lines of steam railway:

Budapest to Szent-Endre.
Budapest to Czinkota.
Budapest to Soraksar.

They aggregate 35 miles of track.

ARLBERG TUNNEL

The exceedingly difficult country over which they operate, which makes the cost of operating steam locomotives excessive, has caused the Austrian Railway officials and the Bureau of Electric Traction to make extensive plans for the electrification of steam trunk line systems. The abundant water-power available will save Austria's coal supply and reduce the operating cost.

It was announced in 1907, that the Arlberg Tunnel Division of the Austrian State Railways would be electrically equipped. This division lies between Innsbruck and Feldkirch in the Austrian Tyrol, and forms a part of the through line from Vienna via Innsbruck and Zürich to Paris. The division for which electrification is proposed is 140 miles long and is single track, except for a double track line at its summit 7 miles long. The maximum grade on the west side is 3.14%, and on the east side 2.64%. Curves are numerous, but of large radius. 40 trains per day are run over the line in each direction. Of these trains, one-third are passenger and the balance freight. Three phase locomotives will be used of 3,000 horse-power each, weighing 60 tons. This will enable 25% to 30% greater speed to be made than under steam, and the capacity of the line will be increased 50%. It is estimated that 50 locomotives will be required, 5 or 6 of which will be necessary for a reserve. An hydraulic plant of 40,000 to 50,000 kilowatts will be required.

It is probable that the tunnel will be electrified first, and should the results be found advantageous, the electrification will be extended to cover the scope indicated. The tunnel is 7 miles long. It was announced in November, 1907, that Mr. C. L. Demuralt of New York had been appointed consulting engineer to the Austrian Government to electrify this tunnel.

SWEDEN

The Swedish State Railways comprise two north and south lines with very few branches. Their electrification has been determined upon by the Government in order to take advantage of available water power, and in the belief that the price of coal will soon rise to a point at which it will be more economical to operate the roads electrically than by steam locomotive traction. For the present, it is estimated that electrical working will produce somewhat of a deficit, but it is considered to the good of the nation to expend slightly more money, and keep it in circulation within the kingdom, than to send money outside of Sweden for coal. The Swedish Government, in 1904, began to make arrangements to acquire water powers to be utilized in their electrification work. In 1905, the Government asked a grant of 4,000,000 crowns to buy water falls for use in electrification work and, in 1906, a bill passed Parliament authorizing a grant for the purchase of water falls belonging to private individuals with a view to utilizing them for power on electric railways. It was proposed expending $1,250,000 for purchasing water falls considered necessary for working railways in the near future.

According to Mr. Dahlander, the electrical engineer for the Swedish state railways, the lack of feeders to their roads taken in connection with the sparse traffic, presents a very unfavorable condition as regards the economy of electrification and, consequently, all the changes will be made at the least possible cost. One favorable circumstance, however, is the availability of water powers which in general are quite near the main lines so that expensive transmission systems can be dispensed with. To fill the power gaps which would be left by the 17 hydro-electric plants, totaling 80,000 horse-power, there will be 5 steam stations totaling 22,000 horse-power. The fuel to be used for these stations is a turf which has been found unavailable for locomotive use. The annual expenses for interest on the investment maintenance and renewals of the transmission lines, hydro-electric and steam power stations, operating cost, wages, etc., are figured at $2,667,500, while a saving resulting from giving up the steam service is estimated at $2,181,500, leaving a yearly deficit of $485,000. On this basis, the Swedish Government has consented to electrification in the belief that the present price of coal (about $4.73 per ton) is an extraordinarily low one, and if the price of coal should advance only $1.45 (and at times it has been $3.05 higher), electrical operation would be cheaper than steam. An increase in the traffic would also involve less expense with electrical operation than with steam, as in the latter case the cost is proportionate to the number of trains. Mr. Dahlander estimated the cost of transmission system per kilometer at $3,637.50; cost of locomotives per kilometer $2,425; the charge per horse-power year at the hydraulic plants at $11.64, and the average for all hydraulic and steam stations would be $14.00 per horse-power year.

In 1904, it was announced that experiments would be made on the line between Stockholm and Jufra, and that a temporary power station would be installed at Tomteboda, bids being called for on the proposition.

Two electric locomotives and two motor cars were ordered in 1906 for experimental work. It was determined to adopt the single-phase system, and to experiment on various line voltages.

In 1905, an appropriation of $115,000 was made to carry out experiments on the lines near Stockholm above referred to. The first section electrified was the 4-mile section between Tomteboda and Vartan. The first trials were made in June, 1905, 18 round trips a day being made over this section as a rule, but occasionally none by electric trains. It was planned later to install regular service between the Stockholm Railway Station and the suburban town of Tarfoa, over a 4-mile stretch of double track, and to institute a freight haulage by electric locomotives between Tomteboda and Vartan.

A catenary construction was adopted for the main line and experimental line voltages carried from 5,000 to 20,000. Passenger trains are made up of motor cars and trailers, and freight is hauled by electric locomotives. As soon as these experiments are finished, the electrification of the entire state line will be undertaken.

HELSINBORG–RAA–RAMLOSA RAILWAY

In December, 1906, there was completed the electrification of a light railway connecting Helsinborg with Raa and Ramlosa. Helsinborg is a seaport town of 35,000 inhabitants; Raa is a fishing town; while Ramlosa is a seaside resort. The road was originally a narrow gauge steam road, but the gauge was broadened and new rails laid when it was electrified.

Trolley construction was adopted. The line is 11.8 miles long and of double track. The line from Raa to Ramlosa is only operated in summer; the line from Helsinborg to Raa, 4 miles long, is operated the year round. Power is supplied from a gas-engine power-plant.

Upon completion of the electrification, 17 trains each way were put on, against 9 under steam. 200-ton freight trains are hauled by electricity.

BELGIUM

State-owned roads in Belgium, in general, are small lines. At the same time, some of them support a reasonably dense traffic. Mr. Em. Uytborck visited the United States in 1907, in behalf of the Belgian government, to make investigations into electrical traction with a view toward applying it to certain Belgian lines. It has been decided that these would be equipped with direct-current apparatus, current being supplied by a third rail, but the scope of the contemplated electrifications has not yet been made public.

BORINAGE RAILWAY

This railroad is owned by the Société Nationale des Chemins de Fer Vicinaux, operating about 1,300 miles of very light roads in Belgium. The conversion of this road was decided upon in 1903; 12 miles of road were electrified at first, an announcement being made that it would be extended to 77. The line connects several coal-mining towns and runs largely along their streets. The maximum grade is 7.1%. It is little better than a street railway proposition.

The single-phase system has been installed with overhead trolley and overhead return. 6,600 volts is carried on the feeder wire and 600 volts on the trolley. An hourly service each way has been put on, trains being composed of one motor and one trailer car. The motor cars are capable of hauling two loaded freight trailers.

Ultimately five lines will be converted, largely single track, with some double track. These are:

St. Ghislan to Framieres	9.6 miles
St. Ghislan to Eugies	6.3 miles
Quaregnon to Eugies	6.4 miles
Quaregnon to Framieres	7.4 miles
Paturage to Wasmes	6.8 miles

NORWAY

A small and unimportant road between Hafslaund and Sandesund has been converted into an electric road. Freight is hauled by means of electric locomotives.

CANADA

NIAGARA, ST. CATHERINES & TORONTO RAILWAY

This was originally a steam road built in 1886 and changed into an electrical trolley line in 1899-1900, the first car being run under electrical operation, July 19, 1900. It extends from Niagara Falls, Ontario, to St. Catherines. The road had fallen into the hands of a receiver under steam operation and had been sold under the hammer. It has sidings to more than 15 industrial plants and has track connection with the Michigan Central, thus giving the latter competition with the Grand Trunk.

In addition to operating an interurban-railway passenger traffic, because of its connections to industrial plants, it went into the business of freight-handling. Since 1901, owing to the greater volume of business done, the road has been operated at a profit; whereas under steam operation it fell into financial difficulty. In 1904, the road was acquired by the Canadian Pacific railway. At present, freight is handled partly by electricity and partly by steam, one electric and one steam locomotive being owned.

HULL ELECTRICAL COMPANY

This is a former steam road, 26 miles long, between Ottawa Hill and Aylmer's Junction, which has been electrified. It is now owned by the Canadian Pacific railway. Its rolling-stock comprises 29 cars and two electric locomotives.

LULU ISLAND RAILWAY

This is a branch of the Canadian Pacific, formerly operated by steam. It runs from Vancouver, British Columbia, to Stevetson, 17 miles. Stevetson is a salmon-canning town. The British Columbia Electric Railway, an interurban system operating around Vancouver, leased the road from the Canadian Pacific in 1905 and electrified it as a part of their system.

The road is single-track and a single-pole bracket trolley construction is adopted, a direct-current equipment being used.

QUEBEC, MONTMORENCY & CHARLEVOIX

This was a steam road operated between Quebec, St. Anne de Beaupre, and St. Joachim, a distance of 30 miles. In 1900, an electrical equipment was added and an electrical service put on, running between the usual steam-railway trains. The results obtained were given in a paper read by Mr. E. A. Evans, manager of the Quebec Railway and Light Company, before the Canadian Electrical Association on June 12, 1902:

The electrical equipment cost:	
Electrically bonding existing track	$ 5,022
Overhead trolley, including poles, etc.	68,804
6 large double-truck cars (four 50-horse-power motors running 45 miles per hour and seating 54 passengers)	51,606
600-kilowatt generator and water wheel, 1 rotary transformer, switch-boards, etc	43,430
Total	$168,862

An hourly electrical service was put on in addition to steam, with the following results:

	Increase	1899 Steam	1901 Steam and Electric
Passengers	318,320	253,540	571,374
Revenue	$29,071.39	$44,221.55	$73,292.94
Extra expenses	5,698.46		
Net	$23,372.93		

From June 30, 1901, to June 12, 1902, there was a further passenger increase of 86,392.

AUSTRALIA

In 1903, the conversion of the steam railway between Flinders Street and St. Kildas, Melbourne, was recommended, and the chairman of the Railway Commission of Victoria was sent abroad to study electrification. These are very busy tracks and are separated from the other railway lines. It was stated at the time that without electrification, additional rolling-stock and locomotives would have to be built at an early date, as the demands of the Melbourne suburban service were taking needed rolling-stock from the country. In 1907, Mr. Thomas Tate, chairman of the Victorian Railway Commission submitted his report. The lines for which electrification is proposed are the two busiest suburban lines out of Melbourne. Melbourne has a population of 531,000, a suburban railway service of 149 miles with 149 stations. The passengers carried yearly are 125,000,000, the average journey being 4¾ miles. The aggregate revenue is $1,333,333. There are about 80 trains per day each way over each railway.

The report states that some gain in traffic and gross revenue may be expected, but not a great deal. A belief is expressed that some reduction in the cost of working service will ensue with the two busiest lines electrified, but as to whether it will offset the capital charges can only be seen after investigation.

A further investigation is now in progress — the scope of the proposed electrification under study having been extended.

NOTE.—While this report is in press the following notice comes to hand in the Electric Railway Journal of Sept. 26, 1908:

Charles H. Merz, consulting engineer of London, who is retained by the Victorian government to report on the proposed substitution of electric for steam traction on the suburban lines around Melbourne, as stated in the Street Railway Journal for Dec. 7, 1907, has rendered his report to Thomas

Tait, chairman of the Victorian Government Railways. The report states that electrification is desirable both for financial reasons and for public convenience. The equipment should be carried out in three sections, of which the first comprises 29 miles, the second 65 miles, and the third 124 miles of track. The entire cost would be £2,227,050. The expenses per train mile with electric traction are estimated by Mr. Merz as 11*d*., as against 18*d*. with steam. The total annual expenditure, including 4 per cent on the capital investment, would be more with electricity than with steam, but it is proposed with electricity to give an improved service, which should bring additional revenue.

Mr. Merz recommends the adoption of the multiple-unit system, with an increase of 71 per cent in the train-mileage, but of only 21 per cent in the ton-mileage and an increase in speed which would reduce the number of cars required. He recommends the employment of 800 volts direct-current, with a protected third rail and three-phase power distribution.

CUBA

The Havana Central was organized in 1905, to take over the rights of the Insular Railroad Company and to build an electric railroad line. While building an electrical railroad outright, it succeeded to the franchises of what was designed to be a steam road. The franchise covered the only practical railroad entrance into the harbor of Havana and the business section of the city, together with extensions to various neighboring suburban towns. A line is being constructed for general service, carrying all kinds of freight and providing a frequent passenger service. There will be 125 miles of trackage. From Havana, one branch runs southeast through Cuatro Caminos, Lomas de Candela, Guines, and Providencia to Rosario, 40 miles distant.

A second line runs from Havana to Bejucal, 17 miles distant.

A third runs from Havana to Mariel, 37 miles distant.

Another north and south line runs to El Carmelo, Santiago de las Vegas, and Tuira de Malena 30 miles distant.

The central power-plant will be located at Havana where power will be generated at 19,000 volts and transmitted to 8 sub-stations, from which 600-volt direct current will be supplied to the trolley wires. The main power-station is of 5,000-kilowatt capacity.

In addition to 24 motor passenger coaches, the road has purchased 10 electric freight locomotives each with 4 motors geared for 17 miles per hour and capable of hauling a 300-ton-weight train at this speed. Freight will be handled in standard-box, gondola, and flat cars. In addition, a fast freight and express service in motor coaches will be put on.

CONCLUSION

In addition to the electrification of steam roads and the construction of electric roads to operate under steam-road conditions, there have been steam street-car systems and dummy lines electrified in almost every foreign country, as has been done in the United States. This is true of Great Britain, France, Germany, Italy, and most of the countries in Europe; certain similar lines in Brazil, the Argentine, and Chile have been turned into electric roads. Similar conversion has been made of a steam road out of Tunis. In 1906, the conversion of a steam line between Piræus and Athens, 25 miles long, into an electric line was undertaken. The short steam line from Manila to Malabon was electrified along with the electrical equipment of street-car lines in Manila. The Alexandria and Ramleh road, a steam road built in 1866, running from Alexandria, in Egypt, to Ramleh and Aboukir, was consolidated with the Alexandria Tramway Company and the line transformed into a direct-current trolley system.

In view of the advanced state of the art reached in major applications of electrical traction, these roads are, of course, of no interest, except that they show that the European developments are along similar lines to American ones.

Our object in covering the existent electrifications in such scope has been to show the wide application which has been made of the art. From certain quarters, objection to applying electrification to the Chicago roads has been made on the score that there are physical features of the Chicago situation which prevent the application of electrical traction to the Chicago roads, and that electrification is as yet an undeveloped art. We believe that a consideration of the numerous electrifications which have already been carried out will inevitably lead to the conclusion that any physical condition existent in Chicago can be readily met by the application of devices already in use, and that electrification has passed beyond the experimental stage. Experiments are in progress to determine the relative merits of certain types of electrical apparatus and continual experimentation is being made to better existent types,— but experimentation along similar lines is being made with almost every type of apparatus used in steam-railroad operation. As a matter of fact, it is the history of transportation that no transportation equipment ceases to be experimented upon in an attempt to make it more efficient, until such apparatus becomes obsolete and there is no need for experimentation looking toward its betterment. In our belief, it is almost as justifiable to speak of the experiment of using cross-ties for railroads because experiments are made from time to time to determine the relative serviceability of steel, concrete, untreated-wood or treated-wood cross-ties, as to speak of the experiment of electrical traction because of the controversy as to the relative merits of direct-current and alternating-current apparatus demanding certain observations under operation to determine which may be the better of the two for a given installation.

ELECTRIC HANDLING OF FREIGHT

H. H. EVANS

The handling of freight cars presents one of the largest problems in the electrification of the Chicago terminals. Nowhere has the electrical handling of freight trains reached the volume that it would reach on any of the Chicago terminals, were all the freight therein handled by electricity. In general, electrifications have had to do with terminals into which not a great deal of freight is handled, or else with stretches of track between points at which little freight originates.

The most economically handled tonnage with steam operation is that of freight, which can be held until it accumulates sufficiently to afford long and heavy trains, and which can be despatched regardless of schedule, in order to handle it at the most convenient time. Due to hauling heavy train loads over long distances with few stops, the power consumption with a freight train and, consequently, the coal consumption, is reduced to the lowest possible point. In addition, the heavy weights handled make possible the application of very large and heavy locomotives in which a good many of the space limitations of smaller locomotives are absent, and in consequence of the larger size and of the slow speed at which they are worked, these locomotives may be chosen of a more economical type than is available for passenger train operation. Working up to speed puts much the largest power demand on the locomotive in train operation, and by running the trains over an entire division without stops, it is possible to cut the increment of acceleration above ordinary running resistance to a minimum. Heavy trains, in addition, are economical because the head resistance becomes a proportionately smaller part of the total resistance of the train as the length increases, because the power expended for hauling dead weight of the locomotive is also spread over a wider surface, and because less train labor is required per ton for a heavy train than a light train. For this reason and for the reason that a change in motive power would be required at each end, electric propulsion of freight trains has not been adopted on electrified stretches of track such as that of the West Shore.

For tunnel electrifications, where heavy grades interfere with locomotive capacity, it has been adopted to advantage. Even on straight, level stretches of track with heavy train loads it has been repeatedly mathematically demonstrated that some saving in operating expenses would ensue from electrification, but the savings from the application of electrification to other classes of traffic have been much more attractive to railway officials, that the capital which has been put into electrification has concerned itself principally with the handling of passenger trains.

With the exception of most of the English electrifications and that of the Paris-Orleans electrification in France, virtually all of the foreign electrifications have provided for the handling of freight as well as passenger traffic. Of course, the handling of freight in European countries is very different from that in the United States. It is of nowhere near the volume, and there is nothing like the average distance hauled. In Europe, freight is preferably handled by water, and the principal freight traffic on the railroads is taking this freight to the very nearest seaport. The interior traffic is largely local and shipped in small quantities. Car capacities are small so that small train loads are hauled and there are necessarily more frequent stops, both of these factors making it more favorable for the application of electrical traction.

The freight handling into Chicago, however, is not a handling of heavy trains over level track at constant speeds without stops between division points 100 miles apart. It departs very widely from this condition, and between hauling the heavy trains along the main line without stops and the character of the service encountered in the case of the European freight trains, we should say that the traffic would more closely approach the latter than the former. The terminal freight handling in Chicago is much nearer a switching service than a road service.

As a usual thing the heavy trains stop at yards in the outskirts of the city, where the train is either broken up into smaller units, or a yard engine hitches to it and brings it into the downtown terminal. There are occasional stops and a good deal of slowing down when passing over crossings, through yards or passenger terminals, and over cross overs, past sidings, and other special track work. Instead of a smooth application of power, we have almost continual accelerations. In addition, most terminal entries are used by several classes of trains, the passenger trains, of course, taking precedence over all the freights, and the second-class freights over the third-class. It often happens that a train comes to a contracted portion of the right of way and, because a passenger train is due within 15 or 20 minutes, the freight train stops on the siding and waits for the passenger. Arrived at the yards, the further movement of the freight is, of course, purely switching, when there is much dead time and a great diversity of load.

It is almost impossible to get accurate figures as to the cost of operation of freight trains on terminals. but we believe that it will be generally admitted that the expense per ton-mile of handling freight into terminals will largely exceed the average receipts per ton-mile for freight over the entire division delivering freight into the terminal. This is the justification for switching charges,— usually three or four dollars (depending upon the point) being charged for handling a car from one terminal to another within a city: this amount, of course, being very much in excess of the amount which would be paid if the usual tariff of five or six mills per ton-mile were paid on the contents of the car. In addition, a great many of the freight trains which come over the terminal tracks to the downtown yards are light trains, and it is axiomatic that freight, to be handled profitably, must be handled in heavy train loads; consequently, these light trains are probably handled at a loss. The terminal switching occupies a large part of the freight-train movement. Cars are brought down to the incoming and outgoing freight yards and have to be accurately spotted for loading or unloading purposes, and upon being taken out of the yards, a good deal of shifting back and forth is necessary to make up the train. It is not simply a question of shoving the cars together until they couple and then hauling them out. A freight train must be coaxed and wheedled in getting it together and there is usually more or less trouble getting started. A large part of this is due to the construction of a steam locomotive. The locomotive gets on center and, instead of the cars being pushed ahead, the locomotive backs off center to make another try, and this sort of thing keeps up throughout the whole performance. In making up a train, if the locomotive keep up speed enough to keep from sticking on dead points, there is danger of bringing the cars together with such force as to damage them.

Now, electrical operation would very materially improve these points. With an electric locomotive there is no such thing as getting on center. Acceleration is both more rapid and more economical. When the locomotive stops on a siding, the power consumption stops. In spotting cars, the locomotive can be kept in motion until the car is within an inch of where it belongs and one movement suffices instead of several. The electric locomotive, by its easy motion, can gradually bunt the cars up the track and couple together an entire train ready for hauling out, without damage to the draft-rigging. The electrical locomotive will not be compelled to go down the track at intervals for coal or water. Owing to better acceleration and more flexible control, together with ability to dispense with a good deal of the standby time and dead movement, an electric locomotive will be capable of giving a greater mileage per day in switching or transfer service than a steam locomotive. The electric locomotives can be worked continuously for long hours, while the steam locomotive must be sent to the round-house once in so often for cleaning. With electrical operation, the small transfer freight of say half the tonnage considered desirable for through operation, can be handled at approximately half of the power consumption,— whereas, at present, with steam, it would entail almost as large a coal consumption as a train of double the weight. Transfer freights are in many cases small because, in order to get the trains to transfer points on time, it is necessary to take over what cars are on hand, rather than what tonnage is desired. With electrical operation, a much more intensive working of freight terminals would be possible.

If it affords us a system which will enable us to haul between the downtown terminals and the transfer or make-up yards, fractional trains at fractional power-expenditures, it will enable cars to be shifted back and forth at the downtown terminals and taken into or out of these places as fast as they are loaded or unloaded. This, in a great many cases, will mean practically an entire day saved in the use of a car, for it often happens that a car is almost loaded when the cars are taken out of the yards to be made up into out-going trains and has to be left until the next day. Now, if short trains can be despatched to the out-lying yards at frequent intervals, such a car could be taken out to the yard that same afternoon, perhaps, and could find its place in an out-going train. The delivery or collection of cars from an industrial plant forms a serious problem in freight-handling. Now, the initial or final haul of such a car is at a loss. To collect such cars, even in a heavy industrial section, the steam locomotive collects the cars by twos and threes and finally gets no more than a full train load — as a rule, much less than a full train load is collected. Even with a full train load, the mean load hauled in such an operation, which will often be over a longer mileage than the one to the yard, is only half the train load, with its consequent inefficient expenditure of coal. The largest economies of electrical operation arise when there is the greatest amount of starting and stopping and the greatest variability of load,— which are identically the conditions under which this traffic is handled.

It may be said that the application of electrical working to such tracks

Courtesy Westinghouse Electric & Mfg. Co.

Erie Railroad—Motor Car Train on Electrified Section out of Rochester, N. Y.—Single-Phase Equipment.

or to switch tracks or freight yards, will mean an outlay which will entail larger carrying charges than the savings will offset. This is a matter for demonstration. Per train mile, the savings under electrical operation of freight terminals will be fully as much and perhaps more than the saving to be effected with the electrical handling of passenger traffic. The daily train mileage per mile of track and sidings reserved for freight traffic and storage, will, however, be less than under passenger traffic. On the other hand, the expenditure for electrical equipment per mile of trackage will be very much less for electrical handling of freight in addition to passenger traffic than for the electrical handling of passenger traffic alone. Freight trains move slowly and there is not the necessity for the rigid construction of contact line for freight yards and sidings, supplied to the main line over which passenger trains move at high speeds. The main-line tracks reserved for the movement of freight trains and the distributing tracks for freight yards demand fully as good construction as the passenger tracks. Over the other tracks the trains do not move at very high speeds and over few of them is it necessary to take off extraordinarily large currents. Consequently, the bulk of the freight trackage can be electrified by adopting an overhead trolley construction. A portion of the rest can be electrified by using a light third rail, in the case of direct-current work, or a single-suspension catenary construction from cross catenary wires, in the case of alternating-current work. For industrial sidings and other lightly used tracks, a very cheap form of construction can be adopted. It is probable even, in some cases, that poles may be dispensed with, the span-wires being made fast to anchors in the buildings on each side of the track, as has been done with certain street-railway lines. A freight yard electrified with overhead trolley construction would not even cost as much as street-railway span construction, for instead of a pair of poles spanning two tracks, as in the latter case, we could span some half dozen tracks with a pair of poles, hanging the span-wire from a messenger cable. The freight yards are usually of but a few blocks' length, so that feeders would be unnecessary, the overhead work being electrically tied in to the rails on the main track which passes near. Thus it would be found that the contact-line equipment for the electrification of freight terminals would only cost per mile, between one-half and one-third that of the installation on the main-line trackage. In addition, the amount chargeable per mile of electrified track for investment in power-station and transmission lines would be much less than that chargeable to the initial electrification of passenger trackage.

The heavy freight-train movement in and out of the terminal comes usually in the late evening and the early morning hours when the power-house provided for passenger operation would have little load upon it. The only additional peak-load required to be taken care of at the power-house would be the operation of perhaps one or two trains and of the engines occupied in spotting or switching in the yards simultaneously with the peak of the suburban traffic. This additional peak load would be less in amount than the average power-requirement for freight movement during the 24 hours.

It has been rather well demonstrated that freight can be handled profitably by electricity. Mathematically, it should be handled *more* profitably than at present. The practical demonstration of its more economical handling simply awaits demonstration on a large scale. That it can be handled profitably by electricity, is demonstrated not alone by the experience of European roads, but by the experience of a number of electrical street or interurban railways in this country.

In our investigation we have found considerably over 100 such roads handling freight. With some of them the freight is being handled in very small lots, but a fair proportion is being handled in car-load lots and with a few a certain quantity of freight is being handled in standard railway cars, in car-load lots, in trains of 15 to 30 cars. The handling of freight by such railroads has been going on for several years and is on the increase. It has been claimed in certain quarters that these roads are handling this freight at a loss, but, if such is the case, why do they persist in their practice?

The entrance of the interurban road into freight business has been very bitterly fought by steam railroads. In many cases the steam roads have refused to enter into traffic agreements with such roads or to make use of their equipment. The question arises, if freight-hauling by electricity by these roads is unprofitable why do the steam roads fight them so hard? The better policy to us would seem to be to deliver so much freight to these railroads that they would be put to such a great loss as to throw them into the hands of a receiver, and remove the competition.

There are very few steam railroads that could make money handling freight if they were not allowed to load freight cars for points off their line and to receive loaded cars from other lines. That electric lines have made money when steam railroads have refused them interchanges, indicates an unusual co-efficient of economy in handling freight by electricity.

There has been considerable activity in electric freight-handling around Toledo and Cincinnati and a good deal of it on the Pacific coast. On the Pacific coast, conditions are of course favorable, because water power is available in many instances for the generation of comparatively cheap power and coal is very high; so that a smaller electrical mileage per mile of track will produce sufficient saving to offset capital charges than in the East, because of the coal saving aggregating more. These railroads, also, usually have a large mileage with consequent large power demand, so that the hauling of freight trains does not produce too large increments upon power-house loads. It is this factor which has deterred a great many interurban railway systems from going into the freight business. In a good many cases it happens that the amount of freight which they can obtain is relatively small and would not justify the investment necessary to handle it. Thus in the case of the Waterloo, Cedar Falls & Northern railway, a road first operated by steam then entirely by electricity, it was found that in order to take care of an adequate freight business, it would be necessary to put on much heavier locomotives. This would mean an increased capacity of power-stations and overhead lines, the added investment to be used only one or two days a week. The returns therefrom could not be expected to pay capital charges, so, rather than incur the additional expenditure, the road took to hauling its freight by steam. With the large freight tonnage handled and almost continuous load peculiar to a standard steam terminal, this objection to electric freight-handling would, of course, disappear. Mr. J. D. Hawks, president of the Detroit, Ypsilanti, Ann Arbor & Jackson Railway, sums up the objections to freight-handling on electric lines as follows:

1. The existence of heavy grades on electric roads.
2. The inability to handle heavy enough weights to compete with steam roads.
3. Power-house capacity sufficient to handle an occasional heavy train would entail too heavy a fixed charge.

These objections, of course, would not hold against the electrical handling of freight on the Chicago terminals. There are no heavy grades; electrical locomotives for terminal service on standard railroads can be, and have been, built of a larger capacity than steam locomotives; and the power-house capacity would already be there to handle the heavy trains which would be frequent and not occasional. A number of electric railroads handling freight, which first handled their freight traffic with steam locomotives, have subsequently added electric locomotives to their equipment for handling this traffic. Mr. N. S.

Cooper, in an article in the Street Railway Journal of February 14, 1903, based on 129 replies to letters addressed to electric railway companies handling freight, says: "Almost without exception the business is not only a very remunerative part of their operating, but it grows in volume and scope in a way that leaves the purely passenger business far behind."

The Lackawanna and Wyoming Valley, a third-rail road in competition with steam roads, first hauled its freight with a steam locomotive, but subsequently replaced it with an electric one.

The Cincinnati, Georgetown and Portsmouth replaced its steam locomotives with electric ones for handling freight.

The Philadelphia and Reading, in 1904, bought an electric locomotive for use in freight handling on its Cape May, Delaware Bay, and Sewall's Point Railway branch, this branch being a 7-mile, electrically operated one extending from Cape May to Sewall's Point, and formerly operated merely for passenger service.

The Oregon Water Power and Portland Railway Company of Portland, Ore., handles its freight with electrical locomotives, keeping its three steam locomotives bought for construction purposes on hand as a reserve.

There are a number of electric roads hauling as much freight as small steam lines of equivalent length between terminals. Thus, the Niagara, Buffalo and Lockport line of the International Railway Company handles 20 to 30 loaded standard cars of freight per day between Buffalo and Lockport.

The Niagara, St. Catherines and Toronto Railway had a gross annual freight earning prior to 1900 (under steam operation) of less than $20,000, and in the year ending August, 1903, operated by electricity, was able to show a freight hauling 120% greater than in 1900, and an operating percentage of 52, as against a former loss.

Mr. E. F. Seixas, in an article in the Street Railway Journal, October 19, 1903, says: "With us it is found also that switching service is a source of revenue, which if facilities are available, is remunerative."

The Spokane and Inland Empire Company has its freight and passenger business about equally balanced, and so partakes of the character of a standard railroad. This road has a freight yard in Spokane 300 by 2,000 feet with connections to the standard steam railroad tracks, and interchange agreements with them. The road has a route length of over 100 miles. It goes through a good agricultural country and handles the freight originating therein. It has over 300 standard freight cars of its own and possesses 14 electric locomotives of 500 to 700 horse-power capacity. It handles any traffic offered and compares favorably with steam roads of equal length between terminals. In 1907, the road hauled a 23-car circus train over its line, made up of 5 60-ton Pullmans, 7 standard stock cars, and 11 standard flats, aggregating 2,300 tons.

The Oregon Water Power and Railway Company of Portland, Ore., with lines from Portland to Oregon City, 15 miles, and from Portland to Cazadero, 38 miles, and with 67 miles of single trackage, was especially built for handling freight in carload lots. The freight traffic has been systematically developed until it now forms the major part of the business of the Company, and it is stated that its freight traffic probably exceeds in amount that of any steam railroad of equal length in the west. The Company delivers the freight originated on its lines in carload lots to the Oregon Railway and Navigation Company and to the Oregon Short Line. It has a large freight terminal yard in East Portland handling over 400 cars of freight. It was built to haul logs to the mills. The first summer it was in operation it hauled over 100,000 cords of wood (16 cords to the carload), and also hauled about 10 carloads of crushed stone a day.

The Seattle and Tacoma Electric Railway, with 36 miles between terminals, hauls freight in carload lots in 275-ton trains with electric locomotives.

The Toledo and Western, with 60 miles of main line and a 22 mile branch of road built through undeveloped territory lying between two parallel branches of the Lake Shore and Michigan Southern Railway, 20 to 25 miles apart, handles the freight peculiar to its territory and its freight business has had a big development. In 1905, it secured a 50 mile haul of 600 carloads of construction material to one plant. This road has interchange agreements with steam roads and hauls a good deal of live stock and grain. Trains are handled with electric locomotives. The Toledo and Western is said to be having difficulty in handling all the freight that is offered it.

The East St. Louis and Bellville has two electric locomotives with which it hauls a good deal of coal originating in the mines along its route to East St. Louis. These locomotives haul about 25 loaded coal cars. One line is used entirely for freight service, paralleling a double track passenger line.

Between Edgemont and Lebanon a steam locomotive is used for hauling freight, as it is not considered advisable to invest sufficient money in feeders to handle the freight business of this section electrically. This road is now a part of the Illinois Traction Company (controlled by the McKinley interests), which is systematically developing its freight traffic. It has a mileage of over 400 miles, operates partly under alternating current and partly under direct current. It owns a number of electric locomotives for handling freight and in certain sections handles freight in carload lots. The freight development has hitherto been held back by difficulty in obtaining permission to operate freight trains through the streets of the cities through which the system passes. Belt lines have now been built around some of these cities, notably Springfield and Decatur. The road owns 350 freight cars at present and 15 locomotives, and last year handled over 150,000 tons of coal in carload lots.

The Denver and Northwestern hauls coal from the coal mines at Leyden, Colorado, to Denver.

The Petaluma and Santa Rosa road was built primarily to handle freight and express.

On account of the heavy growth of its freight business a change of gauge of the Puget Sound Electric Company's Tacoma lines became necessary. The Company not only developed a lumber, cord wood, and coal trade, but it put into operation a refrigerator line out in Tacoma.

The Toledo and Indiana, from Toledo to Bryan, 55½ miles, (ultimately, Toledo to Fort Wayne) handles freight in carload lots with an electric locomotive. It parallels the Lake Shore and Michigan Southern, and gets local freight which might otherwise go to that road because it leaves freight at the door of the receiver.

The Atlantic Shore line in Maine handles freight in carload lots with electric locomotives.

The Des Moines and Interurban Railway has a sort of belt line in Des Moines, and handles freight in standard railroad cars with electric locomotives. The line has freight agreements with the Chicago and Great Western, the Iowa Central, and the Minneapolis and St. Louis. The line runs through a sparsely populated country and consists of four radial branches from 6 to 23 miles long. It has a line between Klondike Junction and Flint Valley operated entirely for freight. It hauls a good deal of stock in standard cars delivering them to steam roads for shipment to Chicago. Five mines on the road each ship five cars daily over the Interurban, and it draws additional traffic from brick yards, manufacturing plants, farms, etc. The road's freight business is what makes the road pay.

Some of these roads are in competition with steam roads and because of their ability to despatch freight as soon as received, are gaining a larger and larger share of the local business. It is probable that freight handling by such lines will receive a larger growth in the future, and that a considerable portion of the strictly local business will be handled by electricity, just as the electric roads have skimmed the cream of the local passenger traffic. That the thing pays is evidenced by the continuance of these roads in the business of freight handling. In addition, there is considerable testimony to the effect that it is remunerative. Thus Frederick S. Pratt, of the Executive Committee of Stone & Webster in the Boston and Providence hearing before the Legislative Committee on Street Railways of Massachusetts (incidental to a comprehensive discussion of interurban railways), stated that the Puget Sound line between Seattle and Tacoma was operated at a loss until it began to carry freight. Published statements of the operation of the Toledo and Indiana, show a net profit of about 3 cents per car mile on freight handling. It is stated that the freight business of the Des Moines Interurban is responsible for the road paying. A statement in the press that the Maumee Valley Railway and Light Company had given up handling freight as it was unprofitable at steam railway rates, was denied in a letter given out by Mr. L. E. Beilstern, General Manager of the road, in which he stated that they were "still doing freight business and expected to continue to do so."

To an inquiry made by Mr. J. B. McClary, 45 electric roads reported that the freight business was profitable, 9 were doubtful, 10 were noncommittal, and only 2 reported it unprofitable.

Regarding the Toledo and Western, Mr. G. F. Franklin, general manager of the road, gave out a statement in 1905 that the road could not live through passenger service alone. Mr. Franklin was at one time General Superintendent of the Clover Leaf Route. As he is thus familiar with both steam and electrical operation, we are inclined to believe that freight handling is considered cheaper by electricity on the Toledo and Western than by steam — else it would hardly be persisted in.

We have already touched upon the reasons why freight handling was not included in the two large New York electrifications,— namely, that both enter a terminal, into which no freight goes.

Their freight lines will probably be changed in the near future to a different route from that followed at present and worked electrically. Confirmatory to our remarks regarding the connection of the New

Haven with the Pennsylvania, there was published just prior to the New Haven's electrification an estimate of electrically equipping the Willis Avenue line of the New Haven road and of connecting it across Ward's and Randall's Islands with the Pennsylvania Railroad at Long Island City. The building of the New York Central's freight subway on 11th and 12th avenues with a line across 52d Street to connect with the Grand Central Station was broached by their chief Engineer, George F. Rice, to the New York Traffic Commission, on November 15, 1906. The electric handling of freight by these lines is contemplated, and, we believe, will be consummated in the not distant future.

The objections which we hear to electric traction for freight work are as follows:

1. That it is in the experimental stage; its feasibility has not been proven.

2. That electricity will clutter up the freight yards.

3. That it will increase the dangers of yards.

4. That it will prove expensive in operation — more expensive than steam locomotive switching and hauling.

Let us consider these points seriatim.

1. In our judgment this has been the greatest deterrent to electrification. For the last decade, roads have had estimates made on electrification and opinions have been vouchsafed by experts that freight-handling would pay. There has been discussion as to who should bear the cost of experimentation and stand the losses which always ensue,— since experimentation can never be put on a basis of practical production. Some experimentation will be a necessity, principally to develop the best type of electrical switching locomotives. The present type of steam locomotive represents evolution. Such questions as the diameter of drivers, the use of leading or trailing trucks, the building of engines with high or low centers of gravity, the employment of compound or simple engines, and with compound engines, whether the cylinders shall be tandem or yoke connected, and numberless other points have all had to be threshed out. There will be less experimentation with the types of electric switching engines and with other types of electrical equipment than in the case of steam locomotives, for the following reasons: (*a*) A large number of points involved concern trucks and frames and other parts which can be adapted from steam-locomotive practice, with all the knowledge of past experience as a guide. (*b*) Electricity is nearly a mathematical science. The electrical engineer can figure results to an unusual degree of accuracy. Thus, in the case of the New York subway,

Mr. Stillwell's estimates of the required power-input for different classes of trains came within 3% of the test performance. (*c*) The electrical switching and electrical freight industry is not in its infancy. Mines, industrial plants, belt lines, traction systems, and European electrifications have been switching and hauling freight for years. Yards of sufficient size to have passed beyond simplicity and switching freight trackage many miles in extent, have long been in operation. The freight problem has ample precedent except in volume; and volume furnishes no problems that are peculiar. The passenger-traffic types of locomotives require but few modifications to insure a high-efficiency electric locomotive for terminal service. The large electric houses are prepared now to furnish a type guaranteed to give efficiency in meeting the problems outlined to them. The controversy between direct current of low voltage and an alternating current of high voltage is impossible of solution now, but as each is proving satisfactory, this is not an insurmountable objection. The present electric locomotives employed in the New York terminal electrifications are economic haulers of large units. That phase is proven. When it comes to the small units, economical tractors are proven to the smallest detail. To our mind, since the larger proportion of train movements over the terminal tracks are of small trains, it would be advisable to adopt the policy of handling the bulk of the traffic with small trains. For this, a smaller-size locomotive could be provided and the rheostatic losses kept down. (We are speaking of direct-current equipment in his argument, simply because it is the canonical equipment.) For handling heavy trains, these locomotives could be double-headed. The locomotives will preferably be of geared type or built with large, slow-moving motors. An extension of the present multiple, series-parallel control would probably be deemed advisable so that the 16 motors on a double-headed unit could be connected in the various variations from 8 motors in series to 8 motors in parallel. It has been found on the New York Central that the switching locomotives must be fitted with additional rheostats and it would be preferable to obtain the resistance within additional motors, rather than by dissipating energy. Most of the problems of electric traction for freight and of switching have been demonstrated by years of use. Local adaptation will be controlled by a science that is more accurate than steam economics or almost anything else. As further arguments, we refer to the experiences cited elsewhere, the opinions expressed, and such declared intentions as to future developments as we have discovered in our investigations,— some of which we are not privileged to relate.

2. As to the objection on the grounds that the freight yard would be cluttered up,— in the Grand Trunk yards at Port Huron, the New Haven yards, the storage yards of the Brooklyn Rapid Transit Company, or the yards at the entrance of the Simplon Tunnel, we get an idea as to what this will amount to. The overhead construction is not particularly complicated and the only additional incumbrance added to the yards are posts spanning from four to a dozen tracks. There is sufficient clearance in the yards everywhere for the erection of these posts, as only the end posts require stay-wires; the intermediate posts being no thicker than a man's body, and a clearance being allowed between freight tracks for two trains to pass with sufficient room between for a man to stand. Freight terminal yards have no more complicated trackage lay-outs than the lay-outs at the ends of the passenger stations where a number of tracks converge to two or four tracks. Existent passenger electrifications cover track work which has just as complicated features as can be found in any part of Chicago, and both the third-rail and the overhead construction have been applied in such electrifications. The Port Huron yard is a storage yard from 2 to 10 tracks wide and 2 miles long. They have not found the overhead work objectionable or dangerous.

3. The dangers from electrified yards. Yards are not for trespassers and anything which will increase the fear of a yard will decrease its dangers. The New York Central yards have been very free from accidents. The other freight yards do not report any unusual accidents from current. Industrial yards with electric traction, have no high accident rates. We have already touched upon this question toward the end of the chapter upon the general aspects of electrification, wherein some statistical matter is incorporated. The current voltage of street-car lines of such suburbans as the Aurora, Elgin & Chicago, the Lake Street Elevated, the Northwestern Elevated,— all of which have storage yards of size, is equal to the probable voltage which would be adopted for the electrification of Chicago terminals, yet their accident rates are certainly not prohibitive.

4. It is just in switching that we think electric traction would show the greatest saving over steam traction. The load is very uneven; electric traction is more adjustable than steam traction. The steam locomotive is idle so much of the time and carries full steam all of such time. Here electricity saves. The steam locomotive does not run with equal efficiency in both directions; the electric does. The locomotive runs farther in making a switch; the crew is larger than an elec-

tric crew — when the engine is idle, the crew is idle. With electricity, cars can be spotted more accurately and in much less time. There is no such thing as getting on center. The upkeep is less, round-house charges are less, cleaning is less. It can work longer hours. There is no loss going for coal or water, or other dead runs. Control is better. Acceleration is both more rapid and more economical. The cost of a switching mile is in excess of that of a straight-away mile and the coefficient of inefficiency of switching service is exceedingly high. Much of the waste is in switching and the returns from these economies should be productive in proportion to the importance of the service.

The most considerable objection to electric handling of freight is its volume. To those who are accustomed to the power-requirements of the large urban street-car systems, or electric-lighting requirements, the power required by an electrified terminal in Chicago seems insignificant. Switching included, it is probable that the maximum momentary requirement on the Illinois Central for its entire service would not exceed 15,000 kilowatts, or a rated power-house capacity of 10,000 kilowatts. The New York Central installation in two power-plants designed for passenger and freight traffic and probably for the New Haven load, is 40,000 kilowatts. The Twin Cities plant for street-railway service in St. Paul and Minneapolis is 35,000 kilowatts. The Interborough Rapid Transit Company of New York has an installation of approximately 140,000 kilowatts. The South Side Elevated has 14,000 kilowatts.

The new power-plant at the Gary Steel Works will have 34,000 kilowatts. The smallness of 10,000 kilowatts is apparent when we consider that the larger-sized turbines, of which a number may be located in one station, are now built in sizes of 7,500 kilowatts.

We have suggested that a special type of switching locomotive be provided for the service. For through hauling of heavy trains, the electric locomotives used for the passenger trains will of course be available and the adoption of electrical hauling for such service would give them an opportunity of returning a greater mileage per day and would probably lead to an easier care of rolling-stock demands and a lessened dead mileage. Should electrification be adopted, it is probable that for several years provision will have to be made for a few smokeless locomotives to make side trips, for instance, with stock trains to the Stock Yards. These, of course, may be anthracite or coke burners. Prudence would demand that the work and wreck trains be hauled by a steam locomotive. The incoming and outgoing steam locomotives for attachment to trains at the end of the electrification could be utilized as stand-by locomotives for this service.

There are two extremely attractive by-products of electrification. The first of these is local delivery of parcels and packages over existent steam lines. A considerable problem is before the large merchants of this city as to how they shall handle their deliveries to out-lying districts. Distances are becoming so great that it is becoming uneconomical and largely impossible to handle deliveries from the center of the city. Automobile delivery has been resorted to, but it has not proven altogether satisfactory. The practice has grown of building barns in outlying sections to supply a district contiguous thereto and deliveries from that section are teamed out or sent out in automobiles, there to be distributed by wagons which ply locally. With the economical use of small trains hauled by light electric locomotives, it would be possible for the railroads to carry such business at a profit for the merchants and with the instant availability of electrical service, such trains could probably be despatched a couple of times a day. The traffic would thus be handled, in the case of the Illinois Central, by putting small sidings at intervals of, let us say, two miles, and at their suburban stations where the station agent can look out for them. A light package delivery train could leave the downtown terminal in the early morning and at noon, let us say, with a car destined for each siding. The train could drop the cars off at the sidings as it proceeded down the line and collect them on its way back. The merchants would have their distributing wagons meet these cars, load from them and distribute the packages to the district adjacent to the station.

The second, and a very important item, is the opportunity of securing larger returns from existent freight-houses. Owing to the tax of freight-handling, these at present are almost uniformly one-story buildings. The material which is handled in them and which is stored in them is handled by the railroad at a poor return on its investment. In general, in the city of Chicago, in the downtown districts, taxes and other fixed charges on property are so high that the one-story building will not bring a sufficient return to more than offset them. If it has been true everywhere else, why should it not be economy for the railroads to build multi-story buildings in place of these one-story freight-houses and secure an adequate return from the ground occupied?

What we have in mind is the utilization of these freight-houses as storage warehouses. It is poor economy to handle them as they are at present handled. Goods are brought into a congested freight-house around which the wagons block each other's way and a long time is taken in loading and unloading. They are teamed across town to some warehouse where they are left until sold,— then teamed back and shipped out to the customer. As the population of the city increases, the cost of teaming grows, and as the extent of teaming grows, the cost to the Chicago tax-payer grows in turn. The large jobbers pay a considerable proportion of the downtown taxes, so their present handling of stock costs them an outlay both in money spent for teaming, in a possible weather damage and in increased taxes. If they could save the teaming and store the goods in a warehouse at a freight terminal, it stands to reason that they would prefer doing so. We have reference, of course, to bulk stocks such as cement, meats, print goods, shoes, etc., which are sold on sample. The procedure would be for the material to arrive in Chicago, be taken out of the cars, carried in elevators to the upper floors of the railroad warehouses and there stored. The larger merchants would keep their stock stored at several terminals. When an order would come in for some of the material, it would be removed from the warehouse and shipped over the line coming into it. If warehouse business is profitable to those who go into it as an investment, we take it that it would be profitable to the railroads, charging equal rates. With equal rates, the jobber would prefer to store his goods with the railroad warehouse and save teaming, since if he should not ship out over the road owning the warehouse, he could load his car there and pay switching charges on it for delivery to the other road. The railroad would have an income-producing property and would also reap an advantage in that they would have preference over the business stored in its warehouses. The jobber would save his teaming bill, which would not only put him to the profit side of the ledger, but would also tend to decrease serious derangement of his business by teamsters' strikes, a thing with which Chicago is thoroughly familiar,— so that both from the public point of view and from the railroad point of view, the erection of such warehouses would be advantageous.

Now, the railroads in Chicago, in general, own the property on which their freight-houses are constructed. The Illinois Central, for instance, is debarred perhaps from erecting buildings over its right of way on the lake-front, but the freight-houses at the foot of South Water Street are built on property which was formerly a part of the Fort Dearborn military reservation, and as it was purchased outright from the United States government it is consequently free from restrictions. The charters of certain railroads may not permit them to enter a warehouse business, but their entry into such business seems commercially so advantageous to Chicago that we believe they would meet with the hearty support of the citizens of the city in an endeavor to amend their charters to provide for their entering this business.

It is not practicable to construct such storage warehouses at present, because the damage to goods from the smoke would be large and the fire risk too heavy. But the adoption of electrical working would do away with the smoke and make the warehouses clean and would reduce the insurance rate. In addition, such warehouses could be extended over the entire freight terminal area, the tracks passing underneath them.

The advantages of electric freight hauling are:

1. Economy of operation from the use of the same power for the three forms of the service.

2. Economy of upkeep from keeping sulphur-containing smoke from contact with equipment and buildings.

3. Economy intrinsic to the freight service.

4. More rapid service.

5. Better use of the tracks.

6. Better use of storage space for engines.

7. Better use of warehouses and the adoption of a storage-warehouse system.

8. Possible double-decking of tracks into warehouses when the future demands it.

9. Smoke abatement.

10. The affording to the public of a city freight service analogous in its bearing to through freight service, to the bearing of suburban passenger service to through passenger service.

On this matter we beg to offer the opinion of Mr. E. H. McHenry, vice-president of the New York, New Haven & Hartford railroad, which we consider contains much of the essence of this matter. This was published in an article in the Street Railway Journal, August 17, 1907:

"Numerous analyses and comparisons of the comparative costs of electric and steam operation have been published from time to time, which tend to prove that a considerable saving in fuel, engine repairs, and other operating expenses may be expected. Under favorable conditions this saving may be large enough to pay interest and other fixed charges upon the additional constructing investment and still leave a satisfactory margin to apply to dividends. Under general conditions, however, it is altogether improbable that the saving resulting from the simple substitution of electric for steam power will be sufficient to justify the additional investment and financial risk.

"In changing the method of motive power on existent railways, the conditions are by on means so simple as in the construction of new lines, as in the former case a great amount of capital already invested must be sacrificed, and the problems of adaptation to existing conditions are peculiarly severe. In particular, the transition stage in bridging over the gap between steam and electric operation is both expensive and difficult, as the change affects train lighting and heating, telegraph and telephone service, signalling and track maintenance, for which both temporary and permanent provision must be made. The simultaneous maintenance of facilities and working forces for both steam and electric service within the same limits, will be rarely profitable, for the reason that a large proportion of expense incident to both kinds of service is retained without realizing the full economy of either.

"To secure the fullest economy, it is necessary, at least, to extend the new service over the whole length of the existing engine stage or district, and to include both passenger and freight trains, and in this connection, it is interesting to note that in the case of the New Haven company, the passenger-train mileage forms so large a proportion of the whole, that no additional generating and transmission capacity will be needed when electric traction is extended to freight service.

"The application of electric traction to heavy railway service will probably be governed by other and more important considerations than its mere relative cost as a motive power under similar conditions, as illustrated in the development of the ordinary trolley service. In this development the commercial value of higher speeds and of increased car capacity is so large that the relative cost of electric versus animal tractive power becomes almost negligible by comparison. Analogous results may be hoped for in the corresponding development of electric traction in heavy railway service, as the new conditions will afford opportunities for at least two radical modifications of existing conditions, quite apart from minor economies.

"In steam service, the weight and speed of trains are limited by the horse-power capacity of the locomotive, which generates its own power, and there are but few locomotives which can generate sufficient steam to utilize their full cylinder tractive powers at speeds in excess of 12 miles an hour. Consequently, any increase of speed beyond certain limits can only be attained by sacrificing train tonnage in a corresponding degree. The division of the train-mile cost by the lesser number of tons, increases the ton-mile proportionately.

"The high cost of fast freight service is principally due to the effect of a diminishing divisor, while it would seem that electric traction should permit high speeds without sacrificing commercial tonnage, as, with a relatively unlimited source of power at command, the maximum draw-bar pull permitted by the motor design may be maintained at all speeds.

"The commercial value of high speed in freight and passenger service is so great, that the prospect of escaping the present penalties accompanying reduced train capacity becomes doubly interesting.

"Hardly less important is the opportunity afforded at the opposite end of the scale for the economical operation of trains of minimum capacity. The train capacity cannot be reduced, without loss, below the point where the earnings equal the train-mile cost, and if the cost cannot be reduced proportionately with reduced capacity, the inferior limit of capacity may be unnecessarily large. In steam service the irreducible elements entering into the train-mile cost are so large, that it is rarely profitable to operate trains earning less than 40 to 50 cents per mile. In contrast, electric service permits an extreme reduction of the train length to single-car units, costing to operate but 10 to 15 cents per car mile. Hence, the frequency of service may be increased and the rates reduced, which in turn will react upon the volume of traffic, with the final result of increasing both gross and net earnings.

"It may, therefore, be claimed for electric traction, that it will extend the limits of profitable operation of high-speed heavy trains and also of light trains of low capacity.

"Other, but relatively minor advantages are possible in the effect upon earnings, due to the elimination of smoke, gases, dust, cinders, and heat, the better ventilation or cars, the extension of electric train lighting and heating, and of the effect upon expenses due to the concentration of power-production in large and economical power-houses, a reduction of engine repairs, an increase of effective engine and train mileage, a more or less complete elimination of engine-houses, turn-tables, fuel-stations, water-tanks, cinder-pits, and other operating facilities, the consolidation of power-requirements for traction, pumping, operating shops, elevators, and general uses, and the use of current for lighting switch lamps, stations, and other buildings.

"Finally, the availability and value of real estate and structures at large terminals will be greatly augmented by the possibility of using two or more superimposed track-levels, as strikingly exemplified in the plans for new terminals in New York City, for the New York Central and the Pennsylvania companies.

"A general change from steam to electricity will render unproductive a very large amount of invested capital and create the necessity for the expenditure of additional amounts still greater, but there is no reason to doubt that the transition already in progress will be rapidly extended and applied to all points where congested terminals, high frequency of train service, and low costs of power create favorable conditions."

NOTES ON ECONOMICS

H. H. EVANS

The savings to be gained by electrical operation have been discussed in the chapter on the "General Aspects of Electrification." The savings to be effected will, of course, act to produce a decrease in the operating expenses. The fixed charges and other disbursements against operating income will not be affected by it, except that there will be an increase in fixed charges necessary for the carrying charges upon the investment in the electrical equipment. Operating expenses in general, for local steam-railroad operation, are about 63% of the operating income. The percentage of operating expenses to operating income in the entire United States, according to the summary in the report of the Interstate Commerce Commission for 1906, was 66.8%, and for previous years as follows:

1905	66.78%	1900	64.05%
1904	67.79%	1899	60.24%
1903	66.16%	1898	65.50%
1902	64.00%	1897	67.06%
1901	64.85%	1896	67.20%

The earnings from operation were distributed in 1906, as follows:

Passenger	26.64%
Freight	70.75%
Other earnings	2.57%
Unclassified	.01%

For Group VI, of the Interstate Commerce Commission's classification, in which is included Illinois, the percentages of operating expenses to operating income were:

1906	63.91%	1900	61.91%
1905	64.45%	1899	61.18%
1904	65.90%	1898	62.17%
1903	62.72%	1897	62.84%
1902	61.48%	1896	60.80%
1901	63.00%		

And the earnings from operation were divided as follows:

Passenger	25.33%
Freight	70.79%
Other earnings	3.88%

For the United States:

For 1906, the average revenue per passenger mile in cents, was	$2.03
The revenue per ton of freight per mile	.00748
The revenue per train mile of passenger trains	1.20338
The revenue per train mile of freight trains	2.60804
The revenue per train mile of all trains	2.07547
And the average cost of running a train, all trains	1.3706

The 66.8% of operating expenses was distributed in the report as follows:

Item	Amount	Per Cent						
	1906	1906[1]	1905[2]	1904[3]	1903[4]	1902[5]	1901[6]	1900[7]
Maintenance of way and structures:								
1. Repairs of roadway	$164,468,769	10.726	10.393	10.348	11.093	11.331	10.924	10.99
2. Renewals of rails	21,962,249	1.432	1.316	1.298	1.386	1.521	1.676	1.138
3. Renewals of ties	38,467,183	2.509	2.657	2.519	2.487	2.838	3.140	3.036
4. Repairs and renewals of bridges and culverts	33,846,281	2.207	2.319	2.228	2.461	2.593	2.730	2.703
5. Repairs and renewals of fences, road crossings, signs, and cattle guards	6,330,746	.413	.446	.437	.527	.625	.598	.616
6. Repairs and renewals of buildings and fixtures	35,325,172	2.304	2.114	2.147	2.590	2.562	2.417	2.466
7. Repairs and renewals of docks and wharves	3,695,079	.241	.208	.209	.235	.220	.283	.308
8. Repairs and renewals of telegraph	2,717,385	.177	.171	.179	.165	.173	.158	.153
9. Stationery and printing	459,273	.030	.028	.029	.032	.031	.029	.030
10. Other expenses	3,938,667	.257	.132	.125	.209	.361	.317	.352
Total	$311,210,804	20.296	19.784	19.519	21.185	22.255	22.272	21.797
Maintenance of equipment:								
11. Superintendence	$ 8,612,019	.561	.565	.567	.559	.601	.599	.597
12. Repairs and renewals of locomotives	123,893,482	8.080	8.290	7.904	7.408	7.246	6.695	6.730
13. Repairs and renewals of passenger cars	30,177,532	1.968	1.971	1.951	2.044	2.157	2.277	2.263
14. Repairs and renewals of freight cars	138,141,925	9.009	8.199	7.777	7.442	7.432	7.436	7.687
15. Repairs and renewals of work cars	4,107,826	.268	.242	.231	.242	.245	.233	.252
16. Repairs and renewals of marine equipment	3,552,558	.232	.191	.154	.177	.215	.234	.251
17. Repairs and renewals of shop machinery and tools	10,252,866	.668	.663	.704	.696	.643	.605	.604
18. Stationery and printing	721,291	.047	.043	.042	.046	.044	.043	.043
19. Other expenses	8,633,469	.563	.601	.637	.519	.544	.507	.502
Total	$328,092,968	21.396	20.765	19.967	19.133	19.127	18.629	18.929
Conducting transportation:								
20. Superintendence	$ 27,235,858	1.776	1.803	1.779	1.742	1.711	1.726	1.831
21. Engine and roundhouse men	142,230,807	9.275	9.404	9.550	9.562	9.401	9.340	9.476
22. Fuel for locomotives	170,499,133	11.119	11.278	12.128	11.675	10.776	10.602	9.809
23. Water supply for locomotives	9,964,616	.650	.660	.659	.614	.623	.612	.599
24. Oil, tallow, and waste for locomotives	5,903,014	.385	.392	.397	.389	.366	.361	.365
25. Other supplies for locomotives	3,827,547	.250	.238	.248	.232	.218	.206	.188
26. Train service	97,757,296	6.375	6.536	6.735	6.677	6.737	7.011	7.244

Item	Amount	Per Cent						
	1906	1906	1905	1904	1903	1902	1901	1900
Conducting transportation—Continued:								
27. Train supplies and expenses	$23,871,258	1.557	1.583	1.581	1.552	1.500	1.471	1.467
28. Switchmen, flagmen, and watchmen	66,805,942	4.357	4.336	4.386	4.313	3.984	3.848	3.944
29. Telegraph expenses	26,853,012	1.751	1.790	1.788	1.754	1.784	1.785	1.812
30. Station service	96,710,193	6.307	6.438	6.605	6.664	6.832	6.947	7.109
31. Station supplies	9,362,704	.611	.646	.686	.667	.676	.672	.679
32. Switching charges—balance	4,490,989	0.293	0.303	0.280	0.244	0.272	0.319	0.340
33 Car per diem and mileage—balance	18,885,086	1.231	1.358	1.358	1.400	1.480	1.618	1.800
34. Hire of equipment—balance	3,082,822	.201	.219	.195	.214	.180	.161	.223
35. Loss and damage	21,086,219	1.375	1.426	1.279	1.094	.990	.819	.764
36. Injuries to persons	17,466,864	1.139	1.156	1.196	1.120	1.048	.911	.910
37. Clearing wrecks	4,601,240	.300	.259	.275	.284	.221	.189	.173
38. Operating marine equipment	10,502,581	.685	.714	.696	.745	.721	.862	.866
39. Advertising	6,467,954	.422	.430	.418	.428	.429	.428	.432
40. Outside agencies	20,731,859	1.352	1.419	1.411	1.449	1.579	1.615	1.519
41. Commissions	267,394	.017	.017	.022	.044	.077	.089	.151
42. Stock yards and elevators	849,201	.055	.057	.060	.057	.069	.075	.060
43. Rents for tracks, yards, and terminals	26,848,580	1.751	1.727	1.563	1.544	1.519	1.724	1.728
44. Rents of buildings and other property	4,963,862	.324	.347	.382	.411	.440	.440	.464
45. Stationery and printing	9,639,066	.629	.632	.640	.642	.622	.638	.653
46. Other expenses	3,763,815	.245	.318	.353	.376	.416	.510	.579
Total	$834,668,912	54.432	55.486	56.670	55.893	54.671	54.979	55.179
General expenses:								
47. Salaries of general officers	$12,660,837	.826	.842	.841	.823	.925	.984	1.041
48. Salaries of clerks and attendants	21,042,006	1.372	1.340	1.313	1.254	1.244	1.262	1.269
49. General office expenses and supplies	4,028,647	.263	.249	.230	.234	.240	.257	.262
50. Insurance	7,382,113	.481	.496	.471	.432	.412	.384	.349
51. Law expenses	6,938,807	.452	.512	.513	.541	.558	.625	.571
52. Stationery and printing (general offices)	2,783,392	.182	.176	.170	.175	.168	.161	.166
53. Other expenses	4,595,899	.300	.350	.306	.330	.391	.447	.437
Total	$59,431,701	3.876	3.965	3.844	3.789	3.947	4.120	4.095
Recapitulation of expenses:								
54. Maintenance of way and structures	$311,210,804	20.296	19.784	19.519	21.185	22.255	22.272	21.797
55. Maintenance of equipment	328,092,968	21.396	20.765	19.967	19.133	19.127	18.629	18.929
56. Conducting transportation	834,668,912	54.432	55.486	56.670	55.893	54.671	54.979	55.179
57. General expenses	59,431,701	3.876	3.965	3.844	3.789	3.947	4.120	4.095
Grand Total[1]	$1,533,404,385	100.	100.	100.	100.	100.	100.	100.

[1] Based on $1,533,404,385, which excludes $3,472,886, unclassified.
[2] Based on $1,387,043,027, which excludes $3,559,125, unclassified.
[3] Based on $1,336,476,325, which excludes $2,419,928, unclassified.
[4] Based on $1,254,936,972, which excludes $2,601,880, unclassified.
[5] Based on $1,114,266,660, which excludes $1,982,087, unclassified.
[6] Based on $989,654,973, which excludes $40,742,297, unclassified.
[7] Based on $923,432,555, which excludes $37,995,956, unclassified.

"Maintenance of ways and structures" will be affected to a small degree; thus, it may be found that there is less wear on the rails. Maintenance of ties may be affected to a small extent, first, because of the saving in ties which are burned from hot cinders, and second, because a lessened pounding of rail will produce a lessened tendency to pulling spikes and consequent shortening of the life of the ties. Buildings and fixtures and metallic structures would be removed from the corrosive action of the gases and there would be a lessened amount of dirt to be cleaned from them. It is probable that these savings will about offset the extra amount chargeable to the maintenance of the current supply system.

"General expenses" should be slightly augmented.

The savings to be expected by electrification may then be expected from the items under "Maintenance of Equipment" and "Conducting Transportation," which form about 75% of the total operating expenses; and since the operating expenses are about 66% of the operating income, it is to items which form approximately 50% of the operating income, that we must look for returns.

The largest savings in train-mile costs are to be expected in the items:

Repairs and renewals of locomotives.

Repairs and renewals of passenger cars.

Engine and round house men.

Fuel for locomotives.

Water supply for locomotives.

Stores for same.

Train service (to a slight extent).

Train supplies and expenses.

Telegraph expenses, switchmen, flagmen, watchmen, injuries to persons, and clearing wrecks will probably be slightly increased in the aggregate, although the probability is that the stimulation brought about by electrification in the case of the suburban service will so far distribute this added cost as to reduce the finite charge per train mile against these items. Repairs and renewals of freight cars might perhaps be slightly less, except that on terminal operation alone the freight cars which receive the advantage would so soon pass off the terminal that there would be no finite advantage to the railroad installing the electrification.

A somewhat closer distribution of operating expenses is published by Byers in his "Economics of Railway Operation" covering the distribution of operating expenses on a large Eastern road in 1902. We give it below:

MAINTENANCE OF WAY AND STRUCTURES

	Per cent	Per cent	Per cent
Track maintenance	1.9		
Applying track material	0.9		
Roadway policing	2.0		
General clearing	0.3		
Total section labor		5.1	
Ballast	0.4		
Rails	1.5		
Ties	1.6		
Track appliances	0.5		
Roadway tools	0.2		
Total section materials		4.2	
Other roadway maintenance	0.8		
Bridges and culverts	1.6		
Buildings and grounds	1.5		
Docks and wharves	0.1		
Interlocking and signals	2.0		
Fences, road crossings, and signs	0.2		
Telegraph and telephone service	0.2		
Total structures		6.4	
Engineering and superintendence	0.8		
Electric traction lines			
Stationery and printing	0.1		
Incidentals	0.1		
Total miscellaneous		1.0	
Total maintenance of way and structures			16.7

MAINTENANCE OF EQUIPMENT

	Per cent	Per cent	Per cent
Locomotives, repairs of	10.7		
Passenger cars, repairs of	1.6		
Freight cars, repairs of	6.9		
Work cars, repairs of	0.1		
Floating equipment, repairs of	0.0		
Total repairs		19.3	
Superintendence	0.8		
Tools and machinery	0.8		
Shops — heating and lighting	0.1		
Watchmen			
Stationery and printing			
Incidentals	0.1		
Total miscellaneous		1.8	
Total maintenance of equipment			21.1

CONDUCTING TRANSPORTATION

	Per cent	Per cent
Station service — passenger........	0.3	
Station service — freight...........	4.3	
Station service — combined........	1.7	
Station supplies....................	0.5	
Stock yards and elevators..........		
Total station service...........		6.8
Yard supervision..................	2.5	
Yardmen.........................	3.6	
Yard engineers and firemen.........	2.2	
Yard locomotives, fuel for..........	1.3	
Total yard service............		9 6
Road engineers and firemen — passenger..........................	1.8	
Trainmen — passenger.............	1.6	
Road locomotives — fuel for passenger...........................	1.5	
Passenger cars — care of...........	0.6	
Other train supplies — passenger....	0.3	
Total train service — passenger		5.8
Road engineers and firemen—freight-	5.5	
Trainmen — freight................	7.6	
Road locomotives, fuel for freight......	7.8	
Freight cars, lubrication...........	0.5	
Other train supplies — freight......	0.1	
Total train service — freight		21.5
Engine-house men..................	2.1	
Fuel station, operation of..........	0.4	
Locomotives, water supply for......	0.7	
Locomotives, stores for.............	0.3	
Locomotives, other supplies for.....	0.4	
Total engine service		3.9
Signalmen........................	0.3	
Highway-crossing watchmen........	0.3	
Policemen........................	0.5	
Total miscellaneous labor		1.1
Signal supplies....................	0.3	
Highway-crossing supplies..........	0.1	
Total miscellaneous material....		0.4
Wrecks, clearing..................	0.6	
Injuries to persons................	0.6	
Loss and damage..................	1.7	
Total casualties...............		2.9

	Per cent	Per cent	Per cent
Switching service..................			
Car service..........................			
Hire of equipment.................	0.2		
Rent of tracks, yards, and terminals.	0.5		
Rent of buildings and grounds......	0.6		
Total debit and credit accounts.		1.3	
Superintendence — transportation ..	1.6		
Telegraph and telephone,— operators of............................	2.3		
Floating equipment,— operators of..	0.6		
Elevator and longshore labor.......	0.1		
Dining cars, hotels, and restaurants			
Motormen and conductors			
Electric traction, power plants, operation			
Stationery, and printing............	0.3		
Incidentals..........................	0.1		
Total Miscellaneous		5.0	
Grand Total — Conducting Transportation			58.3

The distribution of expenses for the Mechanical Department, in which will come the greater savings in electrification, are given by this author as follows:

MECHANICAL DEPARTMENT EXPENDITURES

		Percentage of Total Machinery Department Expense		Percentage of Total Operating Expense	
Repairs........	Locomotives, repairs of..................	30.1		10.7	
	Passenger cars, repairs of	4.5		1.6	
	Freight cars, repairs of	19.4		6.9	
	Work cars, repairs of....................	0.3		0.1	
			54.3		19.3
Plant	Tools and machinery	2.2		0.8	
	Shops, heating and lighting	0.3		0.1	
			2.5		0.9
Engine, fuel and supplies	Fuel for locomotives	27.0		9.6	
	Fuel station operation..................	1.0		0.4	
	Water supply for locomotives	1.9		0.7	
	Stores for locomotives..................	0.8		0.3	
	Other supplies, locomotives	1.0		0.4	
			31.7		11.4
Preparation.....	Engine house men	5.9		2.1	
	Care of passenger cars	1.7		0.6	
	Freight-car lubrication..................	1.4		0.5	
			9.0		3.2
Miscellaneous. ..	Superintendence	2.2		0.8	
	Watchmen				
	Stationery				
	Incidental	0.3		0.1	
			2.5		0.9
			100.0		35.7

The cost of repairing locomotives per 100 locomotive miles, in 1903, is given by Byers as follows:

	1899	1900	1901	1902	1903
B. & O.	$3.63	$4.71	$4.76	$5.47	$7.11
Penn. R. R.	3.99	4.87	5.04	5.57	
Penn. R. R. West					
N. W. System	3.56	4.47	4.57	5.24	
S. W. System	3.94	4.62	5.43	5.70	
B. & M.					3.90
N. Y., N. H. & H.					5.09
D. & R. G.					5.85
Hocking Valley					4.00
St. L. & S. W.					6.07
C. & O.					6.56
N. & W.					5.62
C. & G. W.					6.82
Illinois Central					5.81
C. R. R. of N. J.					8.30
M. S. P. & S. S. M.					6.90
Erie					8.28
L. V.					10.01
C. I. & L.					3.05
Southern					7.69
A. T. & S. F.					9.97

These figures it will be noticed are extremely variable. This comes from the fact that prior to the adoption of the Interstate Commerce Commission system of accounting railroad charges, the systems for such accounts were variable, one railroad charging simply the repairs of locomotives; another railroad charging the acquisition of all new locomotives into the repair fund: and another road perhaps charging into the repair fund the purchase of all new locomotives for the replacement of worn-out ones; new locomotives in addition to regular equipment having a new issue of capital stock against them.

A United States Census Report, issued in 1902, gives the following percentage distribution of gross income of electric surface-operating companies in the United States:— it will be noticed that the operating expenses are 57%

FROM CENSUS REPORT

Percentage Distribution of Gross Income of Electric Surface-Operating Companies 1902, without Commercial Lighting

Gross income	100 %
Operating expenses	57.3%
Taxes	5.3%
Interest, total	14.1%
On bonded debt	12.9%
On other debt	1.2%

Rental of leased lines	12.3%
Miscellaneous deduction	0.2%
Dividends	5.9%
Surplus	4.9%

Freight revenue is .008 of total for all roads in United States.

Below is the percentage distribution of operating expenses in the same report:

	Per cent	Per cent
Maintenance of ways and structures		8.5
Tracks and roadway	5.7	
Electric cable and lines	2.1	
Buildings and fixtures	0.7	
Maintenance of equipment, total		11.7
Steam plant	0.9	
Electric cable, etc., plant	0.6	
Cars	5.4	
Electric cable, etc., equipment cars	3.7	
Miscellaneous	0.5	
Miscellaneous shop expenses	0.6	
Operation of power plant, total		16.2
Wages	3.2	
Fuel	9.0	
Water	0.5	
Lubricants and waste	0.4	
Miscellaneous supplies and expenses	0.4	
Hired power	2.7	
Operation of cars, total		43.9
Superintendence of transportation	1.8	
Wages of conductors	16.9	
Wages of Motormen	17.3	
Wages of other car service employees	1.8	
Car-service supplies	1.3	
Miscellaneous car-service expense	1.4	
Cleaning and sanding track	0.5	
Removal of snow and ice	0.6	
Wages of car house employees	2.3	
iscellaneous, total		18.1
Salaries, general officers	2.1	
Salaries, clerks	1.6	
Printing and stationery	0.3	
Miscellaneous office expenses	0.5	
Store-room expenses	0.2	
Stable expenses	1.0	
Advertising and attractions	1.4	
Damages	5.3	
Legal expenses connected with damages	1.3	

	Per cent	Per cent
Other legal expenses....................	0.7	
Rent of land and buildings..............	0.4	
Rent of track and terminals.............	1.0	
Insurance...............................	1.5	
Wages, supplies, and expenses incidental to electric service, not elsewhere included ..		1.6
		100.0

The capitalization, the system of accounting, and the system of maintenance of surface electric-railway lines are different from steam-railroad lines and too close a comparison of these tables should not be attempted. The tables are useful, however, in affording us a basis of judging what will be the relation between the maintenance of the different portions of the equipment, perhaps. That is, it is not safe to take such statistics and predict from them what the proportion of maintenance of electric motors cars for a standard steam railway will be to the general expenses, or to the maintenance of overhead structures, but they are useful in affording a basis for prediction of what ratio will exist between the maintenance of car bodies and car equipment,— although, even in this case, the statistics refer mainly to light street-railway cars in which the maintenance of motors and electrical equipment will bear a larger proportion to the maintenance of car bodies than would be the case in the heavier equipments used on an electrified steam railway.

COST OF ELECTRIFICATION

In the chapter on Existent Electrifications, the costs, where known, of electrified lines, are given. For convenience, these are tabulated below:

Over-all estimates or costs of electrification projects and of electric railways, embracing power-house, transmission line, sub-stations, line construction, track bonding, and rolling stock:

Road	Kind	Total Cost	Miles	Cost per Mile	Remarks
New Haven	Single-phase double-messenger catenary	$2,750,000	85.8	$32,000.00	Preliminary estimate 21.45 miles, Woodlawn to Stamford (a)
New Haven	Third-rail direct-current	2,876,000			Willis Ave. to New Rochelle and connections. (Not carried out) (b)
West Jersey & Seashore	Third-rail direct-current	2,000,000 to 3,000,000	150.	(?)	

Road	Kind	Total Cost	Miles	Cost per Mile	Remarks
Southern Pacific	Direct-current trolley	1,250,000	14.5		Preliminary estimate 1906
Southern Pacific	Direct-current trolley	1,881,000			Alameda mole preliminary estimate. Statement, Gen. Mgr. Calvin
Southern Pacific	Direct-current trolley	2,500,000			Later estimate
Grand Trunk	Single-phase single catenary	500,000 to 1,000.000			
London, Brighton & South Coast	Alternating-current catenary single-phase	1,250,000			H. M. Hobart
Paris-Orleans	Third-rail direct-current	1,490,000	37.3	40,000.00	Dubois
London & North Eastern	Direct-current third-rail	930,000	82	11,342.00	
Valtellina	Three-phase	1,240,000	67	18,500.00	
Milan-Varese		1,100,000	105.7	10,404.00	Italian estimate

(a) Preliminary estimates covering electrifications of 21.45 miles of four-track road for N. Y., N. H. & H.	$ 570,000
Power-house, excluding real estate (12,000 kilowatts)	1,130,000
35 Locomotives	1,050,000
	$2,750,000

Or about $32,000 per mile, single track. Line equipment $6,650 per mile, single track.

Estimates of George Westinghouse in letter to W. H. Newman, President New York Central railroad, October 27, 1905, for N. Y., N. H. & H. R. R.:

PER MILE FOUR-TRACK LINE

	Alternating Current	Direct Current
Sub-stations	$1,714	$16,150
Contact line	12,436	18,872
Transmission line	1,815	2,181
Track bonding	308	308
	$16,273	$37,511
Which is . . . . per mile of single track.	$ 4,068	$ 9,378

PER MILE DOUBLE-TRACK LINE

	Alternating Current	Direct Current
Sub-stations...............	$ 1,542	$13,840
Contact line...............	$ 6,750	9,436
Transmission line..........	1,815	2,181
Track bonding.............	154	154
	$10,261	$25,611
Which is................. per mile of single track.	$ 5,130	$12,806

35 Electric locomotives costing say $900,000 = $25,715 each.
180 Multiple-unit motor-car equipments, say $775,000 = $4,306 each.

(b) Estimate of N. Y., N. H. & H. R. R. covering proposed equipment (with direct-current third rail) of four tracks from Willis Avenue station, New York, to New Rochelle with extensions to Mt. Vernon, West Farms and across Randalls and Wards Islands to connect with Pennsylvania railroad:

71 cars equipped complete....................	$750,000
4 third rails with top protectors and bonding surface rails with marine cable at drawbridge......	415,000
Feed wires, high-tension wires, pole line.........	336,000
2 sub-stations and apparatus.....................	280,000
Power-house, with all material.................	920,000
Car-house.....................................	100,000
Sundries......................................	75,000
Total......................................	$2,876,000

COST OF TRANSMISSION LINES

Below we give a tabulation of a number of published estimates of various transmission lines. Further details concerning them in general can be found in the chapter on Existent Electrifications:

Road	Kind	Total Cost	Miles	Cost per Mile	Remarks
N.Y.,N.H.& H.	Single-phase			$1,815	Estimate Geo. Westing-house
N.Y., N.H.&H.	Three-phase			2,181	Estimate Geo. Westing-house
Paris-Orleans	Three-phase	$103,000	22.2	4,640	Dubois
Typical	Single-phase			1,200	Lincoln
Typical	33,000-volt single-phase, wooden poles			4,125	A. H. Armstrong, "Stand. H-book"
Typical	33,000-volt three-phase, wooden poles			1,637	A. H. Armstrong, "Stand. H-book"

Road	Kind	Total Cost	Miles	Cost per Mile	Remarks
Typical	33,000-volt three-phase, wooden poles duplicate line			3,392	A. H. Armstrong, "Stand. H-book"
Bergdorf-Thun	16,000-volt three-phase			1,228	Marecha.
Projected	Three-phase			2,000	Italian Government
Typical	Three-phase, poles charged to trolley	22,000	48	470	W. A. Blanck
Typical	Single-phase, poles charged to trolley	20,500	48	427	W. A. Blanck
Typical	Three-phase			1,400	Gonzenbach
Boston & Eastern	Cable line, three-phase			7,920	Published estimate
Boston & Eastern	Aerial line, three-phase			4,000	Published estimate
Typical	10,000 V. 3-phase, No. 0 cable			$840 per 1,000 ft.	Waterman A.I.E.E.
Typical	10,000 V. 3-phase, No. 3 cable			$600 per 1,000 ft.	Waterman A.I.E.E.
Typical	33,000-volt single, No. 4 B. & S. poles incl. with trolley	19,800	36	$550	McLaren

COST OF LINE EQUIPMENT

Below are various published estimates of the cost of line equipment, including contact line, feeders, and track bonding:

Road	Kind	Total Cost	Miles	Cost per Mile	Remarks
N.Y., N.H. & H.	Single-phase	$570,000	85.8	$6,650.	Preliminary estimate
N.Y., N.H. & H.	Single-phase			3,186.	Estimate Geo. Westing-house covering four-track road
N.Y., N.H. & H.	Single-phase			3,452.	Estimate Geo. Westing-house covering two-track road
N.Y., N.H. & H.	Third-rail, direct-current			4,795.	Estimate Geo. Westing-house covering four-track road
N.Y., N.H. & H.	Third-rail direct-current			4,795.	Estimate Geo. Westing-house covering two-track road
West Shore	Direct-current catenary	75,000	6.4	(?)	Between Frankfort and Herkimer
Typical	Alternating-current, steel bridge work, mile double track	10,300	2.0	5,150.	Stillwell and Putnam A. I. E. E.

Road	Kind	Total Cost	Miles	Cost per Mile	Remarks
Typical	Alternating-current, catenary, steel-pole bracket			4,800.	Stillwell and Putnam A. I. E. E.
General				3,500. to 5,000.	O. S. Lyford, A. I. E. E. Oct. 7, 1908
Typical	Third-rail direct-current			2,900.	Lincoln
Typical	Third-rail direct-current double track	10,450 to 5,400	2 2	5,225. to 2,700.	Adapted from Gotshall
Typical	Third-rail direct-current		3	3,410.92	Maurice Hoopes 1901
Typical	Direct-current trolley, span construction equivalent to third-rail			4,421.58	Maurice Hoopes 1901
Typical	Direct-current third rail, wooden shelf, plank protection			4,540.	W. B. Potter
Typical	Third-rail, unprotected			3,400.	Computed from Gonzenbach
Typical	Third-rail, unprotected			4,780.	A. H. Armstrong, "Stand. H-book"
Typical	Third-rail, top contact, protected			5,738.	A. H. Armstrong "Stand. H-book"
Typical	Third-rail underrunning, protected			5,535.	A. H. Armstrong "Stand. H-book"
Typical	600-volt direct-current span-construction, single track			3,326.	A. H. Armstrong "Stand. H-book"
Typical	Same, double track			4,966.	A. H. Armstrong "Stand. H-book"
Typical	600-volt trolley construction single track			2,497.	A. H. Armstrong "Stand. H-book"
Typical	Same, double track			4,420.	A. H. Armstrong "Stand. H-book"
Typical	Alternating-current, catenary trolley construction		single track	$3,103.	A. H. Armstrong, "Stand. H-book"
			double track	5,279.	A. H. Armstrong, "Stand. H-book"
Grand Trunk	Alternating-current, catenary on bridges			10,000.	
Typical	Four-track alternating-current catenary on steel bridges	28,262	4	7,065.	A. H. Armstrong, "Stand. H-book"
Valtellina	Three-phase	340,000	67	5,075.	
Burgdorf-Thun	Three-phase	70,000	25	2,800.	
Seebach-Wettingen	Single-phase			2,400.	Contractors' estimate

Road	Kind	Total Cost	Miles	Cost per Mile	Remarks
Swedish State	Single-phase			$6,060.	Mr. Dahlander
Typical	Third-rail direct-current			6,700.	Marechal
Typical	Span construction, trolley, double track	$4,000	2	2,000.	Marechal
Italian roads	Third-rail direct-current			6,000.	Italian Commissioners' estimate
Italian roads	Three-phase			4,000.	Italian Commissioners' estimate
Entire road	Third-rail direct-current			4,000.	Italian Commissioners' estimate
Boston and Providence	Double track, trolley, span construction, iron poles.	9,178	2	4,589.	Computed from published estimate
Mass. & R. I. St. Ry.	Double track, center pole, trolley	7,376	2	3,688.	Computed from published estimate
Typical	Double track, trolley, wooden poles, span construction direct-current	188,000	60.2	1,567.	W. A. Blanck
Typical	Same, alternating-current, Single-phase	94,000	60.2	7,833.	W. A. Blanck
Typical	Double track, direct-current, trolley, iron poles, not including bonds	8,100	2.1	4,050.	Computed from Arnold report
Typical	Direct-current, third-rail, overhead in towns.	247,800	66	3,754.	Computed from Gonzenbach's figures
Boston & Eastern	Third-rail			5,200.	Published estimate
Typical	Three-phase trolley			1,800.	Waterman
Typical	Direct-current, catenary	242,700	63	3,852.	MacLaren
Typical	Alternating-current, single-phase, catenary	182,700	63	2,900.	MacLaren

ROLLING-STOCK

The largest sizes of motor equipments cost from $10 to $15 per horse-power. With the large sizes used, the number which would be required, and the present low prices of materials, we believe that an estimate of $10 per horse-power would be a safe one for an electrification of considerable size. Or, for the changing over of present suburban cars into motor cars, $5,000 each would suffice for the change, this to cover motors, controllers, electric air brakes, circuit-breakers and lightning-arresters, rheostats, trolley pole, contact shoes, and wiring. For electric locomotives, $30,000 for the larger sizes, down to $15,000 for light switching-locomotives, should be a fair figure. Below we have tabulated a number of estimates on such equipment:

Road	Kind	Costs	Remarks
N. Y., N. H. & H.	Electric locomotives, alternating-current single-phase	$35,000 each	Early estimates
N. Y., N. H. & H.	Electric locomotives, alternating-current single-phase	25,715 "	Estimate Geo. Westinghouse
N. Y., N. H. & H.	Multiple-unit motor-car equipments	4,306 "	Estimate Geo. Westinghouse
N. Y., N. H. & H.	Cars complete equipped with direct-current multiple-unit equipments	10,566 "	Estimate on electrification of four-track line, Willis Avenue to New Rochelle, not carried out
N. Y., N. H. & H.	Electric locomotives	30,000 "	Wilgus, A. S. C. E.
New York Central	Electric locomotives	30,000 "	Wilgus, A. S. C. E.
New York Central	Steel motor cars complete	16,000 "	
Bavarian Railways	Electric locomotives	15,000 "	
Paris-Orleans	Electric locomotives	24,000 "	Marechal
Typical	Electric locomotives, three-phase	19,000 "	Waterman, A. I. E. E.

MAINTENANCE AND REPAIR OF ELECTRIC LOCOMOTIVES

This has been discussed in the chapter on General Aspects of Electrification. Two and one-half cents per train mile seems a fair figure. Below are estimates or actual costs, which have appeared from time to time.

Road	Kind	Cost per Day	Cost per Mile	Remarks
N. Y. Central	Electric locomotives 100,000-mile test		$.0126	200 to 400 ton train over 6-mile track
N. Y. Central	Electric locomotives	$2.02		Wilgus
Paris-Orleans	Electric locomotives		.025	Dubois
N.Y., N.H. & H.	Electric locomotives		.025	W. S. Murray
St. Louis & Belleville	Electric locomotives	2.82		
Buffalo, Niagara & Lockport			.005	
Valtellina, 1904	Electric locomotives		.0138	Czerhati
Valtellina, 1906	Electric locomotives		.018	Stillwell and Putnam
Valtellina	Electric locomotives and motor cars		.0135	Waterman
Valtellina	Electric locomotives and motor cars		.01	Preliminary estimate, Ganz & Company
B. & O. R. R.	Electric locomotives		.192	Muhlfeld
B. & O. R. R.	Electric locomotives		.127	Muhlfeld

MAINTENANCE AND REPAIR OF ELECTRIC MOTOR CARS

Below is a list of published costs, or estimated costs, per car mile of maintenance and repairs to electric motor cars. The estimate of Dawson ("Engineering and Electric Traction Pocket-book"), we give in detail. It seems to coincide very closely in its particulars with results which have been attatined from actual experience; and the costs of power-plant equipment, given by this author, are so accurate, so far as we have been able to check them, that we are inclined to place great confidence in this estimate.

Name	Apparatus	Cost per car mile	Authority
Manhattan Elevated, 1906	Motor cars, each; heating and lighting apparatus included	0.28 cents (for electric equipment)	Stillwell and Putnam
N. Y. Subway, 1906	Motor cars, including heating and lighting apparatus	0.38 cents (electric equipment)	Stillwell & Putnam
Wilkesbarre & Hazleton, 1905	500 horse-power motor cars	0.39 cents (for electric equipment)	Stillwell & Putnam
Lackawanna & Wyoming Valley, 1906	34 motor cars, electric locomotive	0.84 cents (for electric equipment)	Stillwell & Putnam
Niagara, Buffalo & Lockport, 1906	Motor cars	0.79 cents (for electric equipment)	Stillwell & Putnam
Valtellina, 1904	Motor cars and electric locomotives	1.4 cents (per locomotive or car mile)	Stillwell & Putnam
Estimate	Electric interurban cars	$.02 per car mile	Gotshall
Elevated road	Motor coaches	.0125 per car mile	Gotshall
Estimate	Motor coaches	.00961 per car mile	Dawson (c)
Aurora, Elgin & Chicago	Motor coaches	.0138 per car mile	Railroad Commissioners' Report
Chicago & Oak Park Elevated	Motor coaches	.0102 per car mile	Railroad Commissioners' Report
Metropolitan Elevated	Motor coaches	.0155 per car mile	Railroad Commissioners' Report
Northwestern Elevated	Motor coaches	.0190 per car mile	Railroad Commissioners' Report
South Side Elevated	Motor coaches	.0141 per car mile	Railroad Commissioners' Report
Boston Elevated	Motor coaches	.0184 per car mile	Railroad Commissioners' Report
Manhattan Elevated	Motor coaches	.0025 per car mile	Potter
Estimate	Motor coaches	.01 per train mile	Potter
Paris-Versailles	Motor coaches	.024 per train mile	Dubois
Mersey Railway	Motor coaches	.0215 per train mile	A. H. Armstrong (estimate)
Estimate	Motor coaches	.01 per car mile	
Estimate	Motor coaches	.0058 per car mile (for electric equipment only)	Street
Bloomington, Pontiac & Joliet	Motor coaches, single-phase	.007 per car mile (for electrical equipment only)	

COST OF MAINTENANCE OF ELECTRICAL EQUIPMENT PER CAR MILE

(c) Car bodies:	
Including painting, upholstering and all work of any description on the car bodies, except the daily cleaning	$.004
Trucks:	
All labor and material on trucks, with the exception of brake shoes	.00125
Air brakes:	
All labor and material on brake mechanisms, including renewals of brake shoes	.00154
Air compressors and governors:	
All costs of renewals, including labor and material of every description	.00030
Multiple-unit controlling apparatus:	
Covering all labor and material on complete control equipment	.00142
Motors	.00110
Total	$.00961

For a two-motor (125 horse-power each) equipment.
(From Engineering & Electric Traction Pocket-book.)

LINE MAINTENANCE

This will be about $100 to $150 per mile. Below is a tabulation of published results or estimates:

Name	Equipment	Cost	Authority
Estimate	Alternating-current, overhead	$150 per mile	Stillwell & Putnam
West Shore	Direct-current third rail	54.72 per mile	F. J. Sprague
Estimate	Direct-current third rail	$100 per mile	Italian commissioners' estimate
General Av.	Direct-current trolley	$149.11 per mile	Street
General Av.	Cables in conduit	$460.39 per mile	Street
Lancashire & Yorkshire	Third rail insulators (1906)	Under 1%	
Bloomington, Pontiac & Joliet	Single-phase line, first 9½ mos. for 10.4 miles	$43.82 for line	
Valtellina, 1904	Three-phase overhead	$104	Czerhati
Valtellina, 1905	Three-phase overhead	$102	
Paris-Versailles	Three-conductor cables in conduit	$233	Dubois

WATT-HOUR CONSUMPTION FOR MOVING TRAINS

Below is a table under the above heading. It is interesting when all the circumstances of the equipment are known. As a means of predicting the power consumption of a given installation, it is of course entirely worthless, unless the train weights, mean speed, and distance between stops and installations are identical. The probable consumption for each particular class of train and character of run must be computed by plotting speed time-curves and from these the curve or kilowatt input, and from this, in turn, the watt-hours per ton mile. Careful calculation of this kind will give accuracy to within 2% to 3%.

Road	Service	Per ton mile to vehicle	Per ton mile at power-house	Per train mile	Remarks
N. Y., N. H. & H.	Electric locomotive passenger service	44 D.C. 42.5 A. C.			St. Ry. Journal Aug. 24, 1907
General	Electric locomotive passenger service—10 mile run		33 (est)		Stillwell and Putnam
General	Electric locomotive freight service—20 miles per hour		17 (est)		Stillwell and Putnam
N. Y., N. H. & H.	On N. Y. Central zone		41.9		W. S. Murray
N. Y., N .H. & H.	On N. Y. Central zone	36.7	Few stops		W. J. Wilgus
N. Y. Central	On N. Y. Central zone	28.9	Few stops		
N. Y. Central	On N. Y. Central zone	33.8	More stops		
N. Y., N. H. & H.	On N. Y. Central zone	41.9	More stops		
Valtellina	Electric locomotive	58	71.3		
Niederschoenweide Spindlersfeld			72		
Vienna Stadtbahn		56			Estimate
Subaithal			70		
Central London		57			Parshall
Milan-Varese			90		
Milan-Varese		49			
Valtellina			64		
Paris-Orleans		45–65			
Manhattan Elevated		70	82		Stillwell
Central London		50			
Lancashire and Yorkshire			80		
City and South London		55.2			

WORKS COSTS OF POWER IN CENTS, PER KILOWATT-HOUR

We append some published estimates of works costs of power, this including fuel, labor, waste, oil, supplies, water, and running repairs:

Name	Per kilowatt-hour	Authorities	Cost of fuel
General	0.6 cents	Stillwell and Putnam	Coal $3 per ton
West	0.5 cents	Stillwell and Putnam	
N. Y. Central	0.58 cents	Wilgus	Coal $3.05 per ton
General	Less than 0.7 cents	H. G. Stott	
Glasgow	0.56 cents	Parshall and Hobart	
Dublin	0.81 cents	Parshall and Hobart	
Estimate	0.65 cents	Gotshall	Coal $2.40 per ton
Estimate	0.50 cents	Potter	Coal $2.40 per ton
Estimate direct current	0.6 cents	MacLaren	
Estimate alt. current	0.5 cents	MacLaren	
	0.992 cents at car	Chicago City Railway	

Coal for power-plant use in Chicago can be bought in lots of several thousand tons for within two or three cents, one way or the other, of $1 per ton, f. o. b. mines for run of mine coal. This can be delivered in Chicago on the siding, for a price of $1.55 to $1.75 per ton of 2,000 pounds,— depending upon the distance which it is shipped. Labor is comparatively cheap in Chicago, and the use of mechanical stokers is general. With large plants, such as would be used by the railroads, the works cost of power at the switchboard would be four-tenths of a cent or under. This is about the cost at which the large power-plants in Chicago are making current at present. In New York it runs somewhere around one-half cent. This is because coal is higher in New York, labor costs more and there is considerable hand firing, water is more expensive and a great deal of difficulty is had with condenser tubes. The following is a record of actual cost at a large power-plant, where conditions and costs are sensibly equal to those which would be encountered in a large electric-traction power-plant located in Chicago:

	July 1904	August 1904	September 1904	October 1904
Labor	$2,407.03	$2,399.98	$2,463.24	$2,703.03
Coal	5,700.51	5,223.00	5,716.43	7,635.24
Oil	430.00	530.40	706.00	670.00
Waste	53.67	36.40	44.30	48.53
Water	364.67	191.52	267.48	249.10
Supplies	193.60	148.00	267.00	315.00
Total	$9,149.48	$8,529.30	$9,473.45	$11,620.90
Credit by sale of cinders	81.50	76.00	75.00	112.00
Net operating cost	$9,067.98	$8,453.30	$9,398.45	$11,508.90
Total output kilowatt-hours	2,004,520	2,170,720	2,557,000	3,047,000
Total tons coal consumed	4,299	4,132	4,387	6,223
Pounds coal per kilowatt-hours	4.1	3.8	3.5	3.93
Total cost per kilowatt-hour	.00443¢	.0039¢	.00367¢	.00377¢

OPERATING EXPENSES FOR NOVEMBER, 1906

	Total Cost	Cost per Kilowatt-hour
Salaries	$3,926.12	$0.000723
Oil (estimated)	655.00	.000120
Waste	40.63	.000007
Water (4,754,288 gallons)	383.55	.000071
Unloading coal	320.90	.000059
Miscellaneous supplies, shop work, etc. (estimated)	300.00	.000055
Boiler tubes (approximate)		
Amount paid for coal	11,060.76	.002037
One set carbon rings for turbine	185.00	.000034
Total expenses	$16,871.96	$0.003106

Net output to line ......5,428,060 kilowatt-hours.

Coal consumption:	Lbs.	Total lbs.	Lbs. per Kilowatt-hour.
Received in November from our weights		17,628,600	
Estimated stock Nov. 1	4,000,000		
Estimated stock Dec. 1	600,000		
	3,400,000		
Decrease in stock		3,400,000	
Net coal consumption		21,028,600	3.87

For the above plant, the lubricating-oil consumption was as follows:

	Total Gallons	Gallons per Kilowatt-hour
Valve-oil consumption	1,649.5	.303
Engine-oil consumption	734.0	.13
Turbine-oil consumption	300.0	.055
Total	2,683.5	.488

COSTS OF POWER-PLANTS AND APPARATUS

New York, New Haven & Hartford estimates, 12,000 kilowatts, single-phase............... $1,130,000
Or, $94.17 per kilowatt.
New York Central, under $90.00 per kilowatt according to Mr. Wilgus, (Proc. A. I. E. E.)
For 5,200-kilowatt plant (estimate Parshall and Hobart):

	Total	Per Kilowatt
Building	$100,000	$19.20
Boilers, pumps, piping, etc.	62,500	12.00 about
Exciter sets, switchboard and cable	20,000	4.00 about

	Total	Per Kilowatt
4 25-cycle, 3-phase, 94 r. p. m. alternators	60,000	11.50 about
4 engines	120,000	23.00 about
Power-station total	$362,500	$70.00 about

Sub-stations (according to Parshall and Hobart):

4 500-kilowatt rotaries	$20,000	$10.00
15 Static transformers	25,000	12.50
Switchboard, wiring, cables, etc.	5,000	2.50
Building	6,500	3.25
Sub-station total	$56,500	$28.25

Storage batteries $70 to $110 per kilowatt on one-hour rate.
New York subway, 45,000 kilowatts, $7,000,000 = $156 per kilowatt.
Waterman estimated three phase at $70 per kilowatt.

The following is taken from Gotshall's "*Electric Railway Economics:*"

COSTS OF RECIPROCATING STEAM-ENGINE POWER STATIONS PER KILOWATT

	Maximum	Minimum
Buildings	$15.00	$8.00
Foundations	3.50	1.50
Boilers and settings	17.00	9.00
Steam piping, covering, etc	12.00	4.00
Engines	32.00	20.00
Generators	21.00	18.00
Pumps, etc	1.00	1.00
Switchboards, etc	4.00	1.50
Feed-water heaters, etc	2.00	1.00
Wiring conduits, wiring, etc	6.00	3.00
Coal conveyors and coal-storage tanks	6.00	2.00
Smoke stacks and flues	2.00	1.00
Fuel economizers	4.50	2.50
Stokers	3.00	2.50
Ash conveyors	1.50	1.00
Incidentals, such as concrete flooring, etc	2.00	2.00
	$132.50	$78.00

Sub-stations $45 to $38.

GLASGOW POWER-PLANT: ACTUAL COSTS — DAWSON

Four 3,500-kilowatt generators driven by 3-cylinder vertical compound Corliss engines:

	Per Kilowatt
Steam engines	$50.61
Exciter engines	1.46
Auxiliary engines	4.36
Boilers	10.20

	Per Kilowatt
Three-phase generators	12.41
Auxiliary generators	2.43
Exciter generators	.97
Static transformers	9.73
Rotary converters and boosters	18.97
Buildings, including smokestack	21.89
Total	$133.03

APPROXIMATE COSTS OF POWER-PLANT PARTS. (DAWSON, ENGINEERING AND ELECTRIC TRACTION BOOK.)

(English Prices.)	
Cost of railway generators per kilowatt	$30 to $50
Cost of steam plant, complete, Corliss engines	65 to 75
Water-tube boilers	15 to 20
Corliss engines per horse-power	25 to 40
Lightly built engine-house per horse power	$5.00
Feed pumps and injectors per horse power	1.90
Surface condenser, including air and circulating pumps per kilowatt	$10 to $12.50
Ejector condenser per kilowatt	$6.25

Power-plant apparatus is cheaper at present than when the first large power-plants were built. Much of the apparatus which had to be built especially for these plants has now become standard apparatus with consequent cheapening. In addition, the perfecting of the steam turbine has furnished a cheaper type of prime mover than was available at that time. Large engine-driven units cost from $30 to $50 per kilowatt and smaller ones correspondingly higher. If horizontal engines are used instead of vertical ones, these figures may be somewhat reduced. Steam turbines and generators complete, but not including condensing apparatus, sell for from $35 in the 500-kilowatt size to about $18 for the very large units, per kilowatt. A steam turbine and generator can be generally bought for about the price of a first-class Corliss engine alone and the steam economy is about the same, unless very high vacuums are used, when the turbine is at an advantage. In addition, steam turbines take up less floor space and so the cost of the power-plant building and foundations is reduced. The high speeds at which turbines run, make the generation of current at the transmission-line voltage the most feasible thing to do, so that step-up transformers at the power-house are done away with. We recall several small plants which have been built at a complete cost per power-station, including buildings and all equipment and a sub-station within the power-station of about one-fourth the generator capacity, for from $150 to $180 per kilowatt. For large stations of the character employed in a terminal electrification, $90 per kilowatt is an ample figure. This we estimate as follows:

Buildings	$15.00
Foundations	3.00
Boilers	15.00
Piping	10.00
Turbines and generators	20.00
Condensers	5.00
Pumps	1.00
Feed-water heaters, etc	3.00
Smoke stack	2.00
Wiring, etc	3.00
Switchboard	2.00
Coal bunkers	2.00
Coaling apparatus	3.00
Water tunnels, etc	3.00
Miscellaneous	2.00
Total	$89.00

For sub-stations, $40 per kilowatt is a fair figure.

LIGHTING AND HEATING

Lighting will be reduced. For a 60-foot coach, thirty 16-candle-power lamps are employed. A watt-hour consumption of 1,500 watt-hours will be required and if this power is delivered to the car for 1 cent per kilowatt hour, this will make a cost of 1.5 cents per hour. As there will be no charge, practically, for attendance, train lighting will be less, or, at least, no more than at present. According to Street, lighting on elevated roads costs 12% of what it formerly did.

Heating will cost more, if the cars are heated by electricity. An oil or hard coal stove could be installed for heating, but the probability is that the public will demand that electric heaters be installed in motor coaches. For through trains heating will have to be done from oil-fired furnaces carried in the electric locomotives, as is done in the New York Central and the New Haven locomotives. The cost of heating by electricity for motor coaches will not be a wholly added expenditure, because on the very cold days, when heating is at maximum, the saving in condensation of steam which now takes place in the steam locomotives due to extreme cold will not be felt at the power-house and the power consumption for motive power in cold weather will not exceed that in warm weather, whereas, the coal consumption in cold weather in steam locomotives does exceed the summer consumption. Heft estimates the current required for heating a 60-foot coach, as 6 to 12 kilowatts, (which would mean a cost of not more than 6 to 12 cents per hour), and in zero weather, 18 kilowatts per hour. The closest estimate of the cost of electric heating which we have seen, is one made by the Chicago City railway, and which appeared in the Street Railway Journal about two years past. This follows:

HOT-WATER AND ELECTRIC HEATING

Electric heating per car 12 amperes 9 hours = 54 kilowatt-hours at .992 cents	$.536
Interest at 5% plus depreciation at 7% on $80, cost of heater, 365 days divided by 150 days' heating season	.064
Hauling dead weight 360 pounds, 100 miles per day, 365 days per year, at 0.95 cents per day of heating season	.042
Repairs 5 cents per car per day	.050
Interest 5% plus depreciation 3% on additional copper required for electric heaters per day per heater	.038
Cost of electrical heating per day	$0.73
Hot-water heaters:	
80 pounds coal at $8.00	$.32
Interest at 5% plus depreciation 7% on $140	.112
Hauling dead weight, 1,454 pounds, 100 miles per day, 365 days in year, per day of heating season	.168
Repairs	.10
Attendance	.10
Total cost per day, hot-water heating	$0.80

It will be noted that electric heating in the case of a street-railway car was computed to be cheaper than hot-water heating; with trains of several coaches this can not be expected to hold.

ROUND-HOUSE COSTS

These were given by Mr. Street, in an address before the Western Railway Club, as follows:

No. Locomotives Handled	Cost per Locomotive
3,900	$1.35
1,134	1.97
2,750	1.38
3 100	1.20
1,500	1.75
Average 2,476	$1.53

These figures do not include the cost of removing ashes from cinder-pits, cost of handling coal, or cost of supplying sand and operating sand-house, or the cost of steam heat and water. They refer in all cases to cost during fairly warm weather and where water was good and only a small number of boilers required washing.

RESULTS OF ELECTRIFICATION OF ELEVATED ROADS

Mr. J. G. White, in a paper before the International Railway Congress, gave the following statistics of the South Side Elevated and the Manhattan Elevated railroads:

	South Side Elevated	Manhattan Elevated
Date of figures before electrification	1897	1900
Date of figures after electrification	1899	1904
Cost of electrical equipment, about		$17,000,000
Increase in power consumption		37%
Gross receipts before electrification	$ 695,287	$ 9,969,900
Gross receipts after electrification	1,170,381	14,529,188
Increase	475,094	4,559,288
Rate of increase	68%	46%
Operating expenses before electrification	$562,258	$6,104,293
Operating expenses after electrification	669,933	6,717,726
Increase	107,675	613,433
Train miles run before electrification (Manhattan 5 cars)		10,740,183
Train miles run after electrification (Manhattan 6 cars)		11,000,000
Total net earnings before electrification	$133,029	$3,865,007
Total net earnings after electrification	500,448	7,811,462
Increase	367,419	3,946,455
Rate of increase	276%	102%
Per cent excess earnings on cost equipment		23.2%
Per cent operating expenses to gross expenses before electrification	81%	61%
Per cent operating expenses to gross expenses after electrification	57%	46%
Saving per car mile in operating expenses		9.6%

In a paper read before the American Street and Interurban Railway Convention at their Cleveland convention in 1906, Mr. H. M. Brinckerhoff gave the following statistics regarding the operation of elevated railroads under steam and under electricity (quoted from Street Railway Journal):

CHICAGO AND OAK PARK ELEVATED

	Steam Year 1895	Electric Year 1904
Passenger cars	100	123 (inc. motors)
Locomotives	35	42 motor cars
Total car miles	2,721,965	4,550,799
Total passengers hauled	9,936,450	16,005,328
Passengers per car mile	3.65	3.52
Rate of increase		3.6%
Passengers per car per annum	99,364	130,124
Rate of increase		23.0%

	Steam Year 1895	Electric Year 1904
Cost per mile	$0.1174	$0.1078
Rate of decrease		8.2%
Schedule speed, miles per hour	12.5	15
Rate of increase		22%

Period of electric operation 8 years.

SOUTH SIDE ELEVATED RAILROAD

	Steam Year 1894	Electric Year 1905	
Passenger cars	110	254	
Locomotives	31	196 (all motors)	
Total car miles	5,182,598	8,230,415	
Total passengers hauled	13,587,791	32,959,752	
Passengers per car mile	2.52	4	Increase 52.6%
Passengers per car per annum	123,525	129,762	Increase 5.0%
Cost per car mile	$0.105	$0.089	Decrease 16.0%
Schedule speed, miles per hour	13.08	14.95	Increase 14.3%

Period of electric operation 7 years.

BROOKLYN RAPID TRANSIT (ELEVATED)

	Steam Year 1898	Electric Year 1905	
Passenger cars	430	1,002 (inc. motors)	
Locomotives	139	558 motor cars	
Total train miles	5,158,365	22,407,301 (cars only)	
Total passengers hauled	44,170,810	122,166,540	
Passengers per car mile		5.2	
Passengers per car per annum	102,723	121,922	Increase 18.7%
Schedule speeds miles per hour	11.5	15.8	Increase 37%
Cost per train mile	$0.384		

Period of electric operation 6 years.

MANHATTAN ELEVATED (NEW YORK)

	Steam Year 1901	Electric Year 1904	
Passenger cars	1,122	1,356	
Locomotives	134	833	
Total car miles	43,860,158	61,743,000	Increase 40%
Passengers hauled	190,045,741	286,634,000	Increase 50%
Passengers per car mile	4.34	4.65	Increase 2.15%
Passengers per car per annum	169,381	211,382	Increase 24.8%
Cost per car mile	$0.1198	$0.095	Decrease 20.4%
Schedule speed, miles per hour	10.1	15	Increase 48.5%

Period of electric operation 3 years.

METROPOLITAN WEST SIDE ELEVATED

	1905
Passenger cars	420
Motor cars	158
Total car miles	11,352,358
Passengers hauled	46,186,753
Schedule speed, miles per hour	15.4
Cost per car mile	$0.0931

Period of electric operation 10 years.

Mr. Brinckerhoff stated that in all cases a reduced cost was obtained despite higher speeds, which meant an increased power consumption of 30% to 50% In the ensuing periods wages had gone up 15% and coal 20% and the usage was harder because of higher speeds, yet a saving was shown. He referred to the operation of steam trains over the Brooklyn Bridge and stated that the capacity had been increased 100% by taking off the steam switch-engines. Speaking of the junction of the Ninth and Sixth Avenue elevated railroads in New York City where the Ninth Avenue line approaches the junction on a grade and difficulty was had under steam operation because of the trains stalling thereon, he states that it was found difficult to hold a 70-second headway under steam operation and now 50% heavier trains are run on a 33-second headway. He further stated that in the case of the Metropolitan West Side Elevated, motor cars are only out of service 3% of the year for overhauling.

THE SITUATION IN CHICAGO

H. H. EVANS

There are at present 26 roads running trains into Chicago terminals. In addition there are belt, transfer, terminal, and industrial lines which have some or all of their trackage within the city. These run no passenger trains but occupy themselves principally in transferring freight. The Chicago terminals are six in number and are grouped around the edge of the business district on two sides of a square. From one to six lines use each terminal. In general the terminal is owned by one railroad or by a terminal association, and the other roads use the terminal trackage to outlying portions of the city where they enter their own lines. Entry into the terminal is under varying agreements. In some cases the entering road has trackage rights for which some form of compensation is paid. This is either a flat compensation, a compensation per mile of trackage used or a compensation per train mile. In other cases the trains are operated outright by the terminal road for a proportionate share of the earnings.

All trains finish or originate their runs in Chicago — no train passes through the city. The same is true of freight. At present a large portion of the through freight is brought into Chicago and transferred within the city. There is a large clearing yard southwest of the city but it is not in general use. Bringing all this through freight into the city adds materially to the smoke nuisance. If it could be transferred through a system of clearing yards outside the city limits, a reduced expense for handling would be afforded the railroads, a certain amount of congestion of terminal facilities would be avoided, generally about a day would be saved on through shipments in passing through Chicago, and the city would be the cleaner. In the past there have been movements to provide a system of outside clearing yards, but progress has not been made, owing to the reluctance of certain roads to go into the scheme. We would suggest that the city offer whatever aid it consistently can in getting the railroad companies to adopt a system of this kind. This would help the smoke situation and also obviate the autumnal freight congestion in Chicago.

The railroads, starting from their terminals near the center of the city, diverge almost radially. There are numerous interconnections for the transfer of freight:— a belt line within the city, an outer belt line, and an extreme outer belt line starting from industrial towns in north western Indiana and sweeping a broad circle with the city as a center. In general, the tracks within the city are elevated or shortly will be, so that the electrification problem, so far as physical conditions are concerned, is greatly simplified. With the completion of the Grand Crossing elevation, there will be few crossings in the city, of densely used tracks, at grade.

Terminals are as follows:—

THE CHICAGO AND NORTHWESTERN (CORNER OF WELLS AND KINZIE STREETS)

Is used alone by the Chicago and Northwestern trains. A new terminal station is being built at present for this road. The passenger terminal is used for both through and suburban passenger trains, the suburban tracks being at the side of the through tracks and a separate portion of the station being used therefor. The trackage coming into this terminal within the city limits of Chicago, comprises 303.23 miles, of which 68.89 miles are first and second main track and 234.34 miles, yards and sidings. The Northwestern operates a heavy suburban service to points north and northwest — the heaviest in the city, with the exception of the Illinois Central. In round numbers, there are 400 trains a day, at this terminal.

Freight terminals are located as follows:

Wisconsin Division, "in" Corner Grand Avenue and Jefferson Street: "out" same.

Galena Division, "in" and "out," No. 2. North State Street.

All divisions "in" and "out," Corner Sixteenth and Jefferson Streets.

Wood Street, corner Oakley Avenue and Fourteenth Street.

Fortieth Street, "out" corner Chicago Avenue and Forty-sixth Avenue.

North Avenue, "out," 166 West North Avenue.

Deering, "out," Diversey Avenue near Lincoln Street.

Union Stock Yards, "out," corner Exchange and Center Avenues.

UNION STATION (CORNER CANAL AND ADAMS STREETS)

This station is owned by the Pennsylvania railroad. It is used jointly by the Chicago & Alton, Chicago, Burlington & Quincy, Chicago, Milwaukee & St. Paul, Pittsburgh, Ft. Wayne & Chicago, and the Pittsburgh, Cincinnati, Chicago & St. Louis — the two latter being Pennsylvania properties. There are about 240 schedule freight and passenger trains per day on this terminal. Both through passenger trains and suburban trains are run from it, the suburban service being operated on the Chicago, Milwaukee & St. Paul and to some extent by the Burlington, and the Pennsylvania. Coming into this terminal there are 549.91 miles of trackage within the city of which 169.94 miles are first and second main track and 379.97 miles, yards and sidings. Freight-houses are located as follows:

Chicago, Burlington & Quincy, "in" and "out" corner Canal and Harrison Streets.

Chicago, Milwaukee & St. Paul, "in" and "out," corner Fulton and Union Streets. "In" and "out" corner Western, California and Grand Avenues.

Chicago & Alton "in" and "out," West Vàn Buren Street and west side of the Chicago river.

Pittsburgh, Cincinnati, Chicago & St. Louis "in" and "out," corner Halsted Street and Carrol Avenue. "Out," corner Eighteenth Street and Western Avenue.

Pittsburgh, Ft. Wayne & Chicago "in" and "out," No. 2 West Madison Street, west side Chicago river. "Out," corner Eighteenth Street and Stewart Avenue.

GRAND CENTRAL DEPOT

(Corner Harrison Street and Fifth Avenue.)

This terminal is owned by the Chicago Terminal Transfer Company, which is as present in the hands of a receiver. The Baltimore & Ohio is the guiding spirit of the Terminal company. The Terminal company was organized June 4, 1897, on a reorganization of the Chicago & Northern Pacific Railroad Company. On April 16, 1906, a receiver was appointed on a suit to foreclose a mortgage on the property, the interest thereon having been in default for two years. A decree of foreclosure was entered February 20, 1907, pursuant to which the property was advertised to be sold May 3, 1907. By an arrangement between the creditors, the Baltimore & Ohio Railroad Company was directed to deposit with the trustees of the mortgage, a sum sufficient to pay the amount due on the bonds and coupons. The Baltimore & Ohio made this deposit, whereupon all further proceedings under the decree of foreclosure were stayed. The Terminal company operates 250 miles of track in Chicago and vicinity, a large part of its mileage being outside the city limits. The terminal is used by the Chicago Terminal Transfer Company, operating a suburban service to Chicago Heights, and by the Baltimore & Ohio, the Chicago Great Western, and the Pere Marquette. The terminal is used by about 60 schedule trains per day, of which 36 are passenger. The suburban service out of the station is very light. The station is the least used of any in Chicago. Coming into it there are 142.55 miles of trackage within the city limits, of which 50.10 miles are first and second main track and the balance in yard tracks and sidings. The freight-houses are located as follows:

Baltimore & Ohio, "in" and "out" freight-houses, Polk Street, east side of Chicago river.

Chicago Great Western, "in" and "out," corner Franklin and Harrison Streets.

Chicago Terminal Transfer "in" and "out," corner Ogden and Western Avenues.

Pere Marquette "in" and "out," corner Franklin and Harrison Streets.

LA SALLE STREET STATION

(Corner La Salle and Van Buren Streets.)

This terminal is owned jointly by the Chicago, Rock Island & Pacific and the Lake Shore & Michigan Southern. In round numbers there are 180 schedule trains per day in and out of this terminal. It is used by the Chicago & Eastern Illinois, Chicago, Indiana and Southern, Chicago, Rock Island & Pacific, Lake Shore & Michigan Southern and the New York, Chicago & St. Louis. The Rock Island has a heavy suburban service between Chicago and Blue Island and a light one to Joliet. The L. S. and C. & E. I. maintains a light suburban service. In addition, a heavy through passenger traffic is maintained. The freight-houses are located as follows:

Chicago, Rock Island & Pacific, "in" and "out," corner Taylor and Sherman Streets.

Chicago & Eastern Illinois "in" and "out," corner Twelfth and Clark Streets.

Lake Shore & Michigan Southern "in" and "out," corner Polk and La Salle Streets.

New York, Chicago and St. Louis "in" and "out" corner Clark and Taylor Streets.

Belonging to lines entering this terminal there are within the city limits of Chicago 236.41 miles of trackage, of which 156.06 miles are first and second main track and 180.35 miles are yards and sidings.

DEARBORN STREET STATION

(Corner Dearborn and Polk Streets.)

This station is owned by the Chicago & Western Indiana railway which operates in connection with the Belt railway of Chicago. All trackage into the terminal is the property of the terminal company. The following roads enter the terminal:

Atchison, Topeka & Santa Fe; Chicago & Western Indiana; Chicago, Indianapolis & Louisville; Chicago & Erie; Grand Trunk; Wabash.

These roads use the terminal trackage for the following distances:

Atchison, Topeka & Santa Fe, 1 mile; Chicago, Indianapolis & Louisville, 20 miles; Erie, 20 miles; Grand Trunk, 5 miles; Wabash, 20 miles.

Freight-houses are located as follows:

"In" and "out," corner Twelfth Street and State.

Chicago, Indianapolis & Louisville, "in" and "out," corner Taylor Street and Custom House Court.

Erie, "in" and "out," corner Fourteenth and Clark Streets.

Grand Trunk, "in" and "out," corner Taylor Street and Plymouth Court.

Wabash "in" and "out," corner Twelfth Street and Plymouth Court.

Approximately 150 schedule trains enter and leave this station daily of which 120 are passenger. The lines entering this station have an aggregate of 288.94 miles of trackage within the city limits, of which 90.48 miles are first and second main track and 198.46 miles are yards and sidings.

CENTRAL STATION

(Corner Twelfth Street and Park Row.)

This station is owned by the Illinois Central, together with all trackage into it. The station is used by the Illinois Central, the Chicago, Cincinnati & Louisville; Cleveland, Cincinnati, Chicago & St. Louis, Michigan Central, and the Wisconsin Central. There are 100 trains a day, counting freights. In addition, a suburban terminal is maintained by the Illinois Central at the foot of Randolph Street, into which 262 trains per day enter or leave. This is the heaviest suburban service in the city, and as the suburban trackage is a part of the terminal trackage, it is the busiest terminal in the city. "In" and "out" freight-houses for all entering roads are located at the foot of South Water Street and the lake front. The trackage entering the terminal within the city limits of Chicago (and including some trackage outside the city limits which it would be good policy to electrify, should electrification be undertaken) amounts to 325 miles for the Illinois Central and to 41.93 miles for the Michigan Central, 7.57 miles of the latter being first and second main track and 34.36 miles yards and sidings. The other roads entering the terminal do not own mileage within the city limits.

In addition to the roads entering the passenger terminals, there are a number of roads having some mileage within the city limits which are in the nature of connecting or industrial roads. The largest of these is, of course, the Chicago Junction Railways and Union Stock Yards Company, operating the tracks within the Stock Yards. The outside tracks of this company were disposed of last year to the Indiana Harbor Belt railway. This is owned by the New York Central and in electrification plans should be so considered. In general, these lines are either controlled by railroads which operate within the city limits, or else their mileage within the city limits is inconsequential. Some of them are: the Englewood Connecting railway in 59th Street, Chicago, 4.55 miles of track, leased by the Pittsburgh, Cincinnati, Chicago & St. Louis; the South Chicago & Southern, operated under lease by the Pennsylvania railroad; the Chicago & Calumet terminal, leased to Western Steel Car and Foundry Company; the Elgin, Joliet and Eastern about 13 miles of trackage within the city limits, this in the shape of yard trackage in an industrial section; the Chicago, Lake Shore & Eastern 5 miles of trackage within the city limits, in the vicinity of the Illinois Steel Company's plant. These two latter are owned by the U. S. Steel Corporation. The Calumet-Western is a connecting track owned jointly by the Pennsylvania, the Chicago, Rock Island & Pacific, the Michigan Central and the Chicago Junction. The Illinois Northern line extends from Hoyne Av. to Elston Av. and comprises 64,686 feet within the city limits. The Chicago & Southwestern railroad has only 2,273 feet of trackage within the city. The Manufacturers' Junction line is an industrial line of which only 6,100 feet lie within the city limits.

Statistical matter regarding the roads entering Chicago will be found in Appendix C.

In dealing with the electrification of the Chicago railroads, the roads should preferably be considered in groups each comprising all the roads entering a certain terminal. Should electrification be carried out, it would undoubtedly be more economical to electrify all the roads entering a terminal, and it would certainly lead to many complications of operation should only a portion of the roads entering a terminal electrify. It would probably be found advantageous for the railroads entering a terminal to form a terminal association for the electrical conduct of the terminal, similar to the terminal associations which have been formed in the cities where union passenger stations have been built. Such an association would have its electrical transmission lines and cables in common, and a great deal of the trackage belonging to different roads but to the same terminal, would be electrically tied together. It is probable that preferably the electrical locomotives running upon the terminal would be owned by a holding company and used in common. With each road owning its own electrical locomotives, we can conceive of a locomotive owned by the X. Y. &. Z. system waiting at the end of the terminal zone for six or seven hours for its train, with incident loss, and meanwhile five or six trains of the P. D. & Q. system going past, upon which the locomotive might be utilized. The same with the power system. Small power-plants cannot make current at a works-cost under eight-tenths of a cent, and the very small ones, under 1¼ cents. With the extremely uneven load imposed by one railroad, these costs would be further increased. A power-plant common to all the roads entering the terminal could be of such size and would have a sufficiently even load to manufacture current at a works-cost of about four-tenths of a cent per kilowatt-hour. Should all of the railroads eventually electrify, a large central power-plant to handle all the roads would probably work a still further advantage, as the roads handling a large suburban service would materially help out the character of the load for roads handling principally freight. The roads which do not enter the passenger terminals, in general, are either affiliated with the roads that do, or are directly controlled by them, so that their electrification would follow a general electrification. Their efficiency is at present so low, on account of the intermittent employment of their equipment, that it would probably be more economical to electrically equip them, purchasing the current, as has been done with the industrial roads around a great many plants in the United States — notably around smelters and mines.

For the roads which merely touch the edge of the city, it is not believed that the harm they do at present will justify the electrification of these short sections, since, owing to their necessitating a change in the method of operation of merely the end of the road, disorganization of their working will ensue and harm to the road be worked without gain to the public.

Courtesy Westinghouse Electric & Mfg. Co.

New York, New Haven & Hartford Railroad — Alternating-Current Single-Phase Locomotive

This leaves, then, first to be considered, the electrification of six large terminals, each with somewhere near the same contributory trackage and each controlled either by a terminal company or by some dominant interest. It is probable, then, that after overcoming a moderate number of obstructions, the terminal company or the company owning the station could secure the co-operation of other roads entering the terminal in an electrification scheme. The traffic into the terminals is reasonably dense and on the increase. Four of the terminals have a respectable suburban service which should grow larger from year to year. With proper handling of their suburban facilities, it is probable that each of the terminal group could induce the settlement of a populace to support a suburban service along its road in suburban towns and in the end build up a large suburban or local traffic.

Each of the systems entering Chicago, at some portion or other of its route, is restricted to the use of two tracks. Thus, the Northwestern has only two tracks across the bridge over the Chicago River at the foot of its station. The railroads entering the Harrison Street station are also constricted to two tracks over a bridge. The heavy Illinois Central suburban traffic, owing to the use of one track for storage, is entirely carried for a short distance on one track. With the growth of the city, the terminals must inevitably become congested. With the growth of the city there will be a growth of land values, so that the amplification of terminals will become increasingly expensive. Eventually, in order to get capacity, the railroads will be compelled to resort to electrical working of terminals. Meanwhile, it seems likely that for certain of them electrification would net a saving. For all of them, where traffic is dense enough for electrification not to mean a positive loss, it would seem advisable to resort to electrification in order to build up a suburban traffic which will become increasingly remunerative.

Owing to the cheap price of coal, it happens that the absolute money-saving in *fuel* consumption (from which the major profits of electrification are reached in the majority of instances) will be small in Chicago. At present, in most places where electrification has been carried out, coal is about $2.00 per ton higher than in Chicago. It is improbable that the people of Chicago will put up with the smoke from the locomotives much longer and eventually the railroads will be forced to adopt either a smokeless fuel, that is, coke or anthracite, or else to resort to electrification. Coke will cost about $2.00 a ton more than coal, so that then the economic conditions will be sensibly equal to those in other places. Electrification will then be the cheaper of the two with all the railroads. It is only a matter of time before this will come about and it might be as well to take time by the forelock.

We have not gone into the details of the returns to be expected from electrification with all the roads. To do so properly would require a minute investigation into the traffic handled by each road and the expenditures therefor, which would necessarily extend over several months. We have, however, made considerable examination of the Chicago terminals to observe the physical conditions which electrifications would meet with in Chicago, and have met with nothing which would make electrification physically impossible or inexpedient. It is simply a question of economics and, we believe, of larger economics — not a mere demonstration of saving in train handling. The larger capacity of terminals, the added comfort of the public and the possibility of utilization of whole blocks of down-town property, now occupied by terminals, for business and manufacturing purposes by building structures over the electrified tracks, would seem to us the more important considerations.

We have concentrated our investigation upon the Illinois Central terminal. We have done this, not because of any feeling one way or the other toward the Illinois Central, but because the electrification of that road seemed to offer the most fertile field in Chicago, and mainly because of the large interest of the public in getting rid of the smoke from this railroad. We have believed, also, that by making an investigation of the Illinois Central, we could reason from our conclusions what might be advisable in the case of other railroads in the city traversing residence districts and operating a high-class suburban service. Concentration upon the Illinois Central has also been largely brought about because of Mr. Harahan's position that the electrification of his road was a question demanding detailed investigation. We have devoted a great deal of time to an investigation of existent electrifications, because Mr. Harahan, in his letter, took the ground that electrification is still experimental. We have found that it has passed entirely beyond the experimental stage.

In addition to a thorough examination of the physical character of the road, we have prepared an estimate of its cost and the probable savings, and we are led to the conclusion that in addition to being feasible electrification would be desirable. The Illinois Central has about 325 miles of trackage from points at which the suburban traffic originates, to the downtown terminal. It has a station at Twelfth Street and Park Row into which through trains of the Wisconsin Central, the

Michigan Central, the Chicago, Cincinnati & Louisville, the "Big Four," and its own trains come. In addition, it has a suburban terminal at Randolph Street from which a suburban traffic, said to be the largest in the country, is worked. The north and south trackage is the terminal of a large double-track line from the Great Lakes to the Gulf, and there is a section turning west at Sixteenth Street, and running to Omaha and other Western points. Above Twelfth Street there are large freight terminal yards which are used by the railroads which use the terminal trackage. The tracks start with a maze of freight tracks at the foot of South Water Street. At the western side of these at Randolph Street there is a suburban terminal. The tracks gradually constrict to Van Buren Street. From thence to Park Row a number of tracks run, including suburban tracks. At the latter point, the tracks broaden out to form the passenger-terminal trackage and passenger and freight storage yards, which converge again at Sixteenth Street and below. From Sixteenth Street there are six tracks to a point just below Thirty-ninth Street, where the tracks broaden to 7, then to 8. In addition, there are tracks to the Twenty-sixth Street round-house and sidings to a coal yard and breweries. The main tracks between Sixteenth and Forty-third Streets, are used as follows, numbering from the west:

Track 1. For south-bound local suburban trains.
Track 2. For north-bound local suburban trains.
Track 3. For south-bound passenger and through freight trains.
Track 4. For north-bound through passenger and freight trains.
Track 5. For south-bound express suburban trains.
Track 6. For north-bound express suburban trains.

The main tracks between Forty-third and Sixty-seventh Streets, are designated as Nos. 1, 2, 3, 4, 5, 6, 7, and 8, and are used as follows:

No. 1. For south-bound local suburbans.
No. 2. For north-bound local suburbans.
No. 3. For south-bound through passengers.
No. 4. For north-bound through passengers.
No. 5. For south-bound freight trains.
No. 6. For north-bound freight trains.
No. 7. For south-bound express suburbans.
No. 8. For north-bound express suburbans.

At Sixty-seventh Street, there is a branch running southeast a distance of 4.5 miles to South Chicago. This is a double-track line and is used for suburban and freight service. At Sixty-seventh Street, the tracks narrow to six, which are used as follows:

No. 1. For south-bound suburban trains.
No. 2. For north-bound suburban trains.
No. 3. For south-bound through passenger rtains.
No. 4. For north-bound through passenger trains.
No. 5. For south-bound transfer freight trains.
No. 6. For north-bound transfer freight trains.

Between Seventy-sixth and Eighty-fifth Streets, there are four tracks used as follows:

No. 1. For south-bound suburban trains.
No. 2. For north-bound suburban trains.
No. 3. For south-bound through passenger and freights.
No. 4. For north-bound through passenger and freights.

Between Eighty-fifth Street and Burnside, there are six tracks used as follows:

No. 1. For south-bound suburban trains.
No. 2. For north-bound suburban trains.
No. 3. For south-bound through passenger and freight trains.
No. 4. For north-bound through passenger and freight trains.
No. 5. For south-bound through freight destined for Fordham Yard.
No. 6. For freight trains going to the north end of Fordham Yard.

Between Burnside and Blue Island Junction there are four tracks used as follows:

No. 1. For south-bound suburban trains.
No. 2. For north-bound suburban trains.
No. 3. For south-bound through passenger and freight trains.
No. 4. For north-bound through passenger and freight trains.

At Blue Island Junction a single-track line goes southwest to Blue Island, distant 3.8 miles, over which a suburban service is operated. From Blue Island Junction south to the Calumet river there are four tracks used respectively:

For south-bound passenger, suburban, and second-class freight trains.
For north-bound passenger, suburban, and second-class freight trains.
For south-bound third and inferior class freight trains.
For north-bound third and inferior class freight trains.

From the Calumet river south to Flossmoor, at the end of the suburban section, there are two tracks only.

The track running west from Sixteenth Street, used by the Freeport division, is a double-track line and is reached by an incline.

Besides the freight terminal yard at the foot of South Water Street and the passenger terminal at Twelfth Street, there is a large working yard at Fordham, 11.43 miles south of Randolph Street, comprising 42 miles of track; a yard at Burnside, comprising 33.5 miles, wherein are located the shops, the yard being used mainly for equipment storage and repair; and a yard at Wildwood, 16.28 miles south of Randolph Street. There is a small yard containing about 3.5 miles of track at the end of the South Chicago branch, the South Chicago branch being incorporated as a separate railroad. There are about 2.5 miles of yard track and sidings on the Blue Island railway, which is the legal designation of the Blue Island branch. On the Freeport division, there are 1.5 miles of sidings within the city limits. In addition, there are small sidings, connections to industrial plants, and team tracks at various places along the length of the road within the city limits.

The Chicago, Cincinnati & Louisville joins the Illinois Central trackage at Riverdale, 17.22 miles from Randolph Street and runs the balance of the way over the Illinois Central tracks.

The Cleveland, Cincinnati, Chicago & St. Louis owns no trackage within the city limits. It has its trains hauled by the Illinois Central over the latter's right of way, from Kankakee to Chicago, in consideration of a percentage of the business.

The Michigan Central operates its trains from Kensington (14.54 miles) into Chicago, over the Illinois Central tracks. Its trackage rights date back to 1853, when it advanced the Illinois Central the necessary money for the construction of their line from Kensington to a point about Sixteenth Street, in order that it might enter the city from Kensington over these tracks. From Kensington to the city limits, the Michigan Central operates over its own right of way, owning 20,008 feet main track, 19,977 feet of second track and 181,331 feet of siding. Its yards are at Kensington.

The Wisconsin Central trains come on the Freeport-division trackage of the Illinois Central at Harlem Junction. They have trackage rights over the Illinois Central under a 99-year lease from South Water Street, Chicago, to Harlem Junction, 14.37 miles.

The attached table shows the train movement over this terminal system:

Suburban	Distance	Week Days				Sundays		Remarks
		Local		Express		Local		
		N.	S.	N.	S.	N.	S.	
Between								
Randolph and Woodlawn		33	34	..	..	1	1	
Randolph and Sixty-seventh Street		..	2	4	2	..	..	
Randolph and Grand Crossing		1	2	1	..	1	1	
Randolph and Burnside		14	13	3	3	..	..	
Randolph and Kensington		2[a]	1	..	1[a]	1	1	(a) 1 train less each way Saturday
Randolph and Harvey		..	1	5	4	1	1	
Randolph and Homewood		2	..	1	1	..	..	
Randolph and South Chicago		10	9	23	24	22	22	
Randolph and West Pullman		..	..	1[b]	1[b]	..	..	(b) Saturday only
Randolph and Blue Island		5	3	12	14	10	10	
Randolph and Flossmoor		2	5	9	8	11	11	
Kensington and Blue Island		1	1	..	..	..	..	
Twelfth Street and Burnside		2	..	..	..	..	..	
Woodlawn and Flossmoor		..	1	..	..	..	..	
Total		72	72	59	58	47	47	

Through	Distance	Daily Passenger		Sunday Passenger		Daily Freight		Sunday Freight		Remarks
		N.	S.	N.	S.	N.	S.	N.	S.	
I. C. Chgo. & New Orleans line		9	9	8	8	6[c]	6	5	3	(c) 1 train less on Monday
I. C. Freeport Div.		6	6	5	5	4	5	2	4	
I. C. Flossmoor and Fordham		..	..	..	..	2	5[d]	..	3	(d) I train less on Monday
I. C. Addison Passenger		3	3	2	2	..	..	..	..	
Michigan Central		10	10	8[e]	7	2	2	2	1	(e) 1 train less on Monday
C. C. & L.		2	2	2	2	..	..	..	..	
C. C. C. & St. L.		4	4	4	4	..	..	..	..	
Wisconsin Central		5	5	3	3	2	3	2[f]	1	(f) 1 train less on Monday
Total		39	39	32	31	16	21	11	12	

THE THROUGH PASSENGER BUSINESS OF THE ILLINOIS CENTRAL TERMINAL

The through passenger service runs into the Twelfth Street depot. This depot is skirted by the suburban service. A small fraction of the freight service traverses it. From it there come and go 36 trains each way a day. Of these, six are Illinois Central trains which go west at Sixteenth Street; five are Wisconsin Central, following the same route; ten are Michigan Central trains leaving the Illinois Central tracks at Kensington; two are Chicago, Cincinnati & Louisville trains leaving the Illinois Central tracks at Riverdale; four are Cleveland, Cincinnati, Chicago & St. Louis trains, using the Illinois Central tracks to a point near Kankakee, and the remainder are Illinois Central, Chicago division, trains. The Chicago, Cincinnati & Louisville has a trackage contract. The Wisconsin Central and the Michigan Central have trackage arrangements with the Illinois Central, and their trains are drawn by their own engines. The Big Four gets its traction from the Illinois Central.

The Main line trains receive and discharge passengers at eight points within the terminal zone, Twelfth Street to Kensington. The western lines make two stops, Twelfth Street and Halsted Street. All of these trains are the usual type of heavy passenger trains, carrying mail, express, day and sleeping car passengers, and running dining cars in about the usual proportions.

Generally speaking, the trains are not as heavy as the passenger-train units running from Chicago to the northwest. They are heavier than the swiftest units running to the east. They average about like the New York Central into New York City. As these trains are for locomotive hauling after they reach the limits of the electric zone, the heavy unit must be maintained. They require a type of electric engine that is now in fairly general use. This engine costs about twice as much as a steam locomotive per horse-power.

Its advantages are: (*a*) lessened cost of upkeep ($0.05 per train mile less); (*b*) fewer days in shop; (*c*) lessened cost of cleaning; (*d*) saving of cost of getting up steam; (*e*) saving of cost of steam in boilers when work is done; (*f*) greater draw-bar pull.

(The Port Huron engines will start a 1,000-ton train up a 2% grade from a dead stop without backing for slack. They will pull a 1,000-ton train and push another 1,000-ton train on the flat. The strength of pull is not limited to the slipping-point on the rails nor is the force applied to one point on the wheel. With a steam locomotive this point is fairly near the axle and therefore not most advantageously placed. Its efficiency is varying always with the position of the wheel, reaching zero when the piston is on center.)

(*g*) Greater acceleration and greater speed. (Several minutes will be gained getting to Kensington by reason of the eight stops. Anyone who has witnessed a suburban train run around Illinois Central No. 5 by reason of the quick acceleration of the former and the slow acceleration of the latter will understand this point. The piston of a locomotive engine comes to a dead stop twice in each revolution of the drive wheel. The force of electricity is continuous and even.)

(*h*) Greater efficiency under adverse weather conditions. (Wilgus's report on the New York Central locomotive says: "The locomotive is a peculiarly efficient and powerful machine. Although weighing 94.5 tons, complete, as compared with the 171-ton weight of the heaviest steam passenger locomotives in use by the company, its normal rating of 2,200 horse-power is practically twice that of its rival; it has 76½ tons less weight to haul about, thus effecting a saving of 45 % for energy in moving dead tonnage; its concentrated weight per driving axle, 34,250 pounds, is 27% less than that of the steam locomotive, without decreasing the total driver weight available for traction; it is capable of running at will in either direction, without decreasing the total driver weight available for traction; it is capable of running at will in either direction, without the delays and expense of going to the turn-tables; it occupies little more than half the track space of the steam locomotive — an important advantage in terminals — and it is much more quickly started and stopped.")

The present schedule requires about 42 engine hours in each 24 hours for both ways; 21 engine hours in and 21 engine hours out. The most advantageous arrangement of schedules, then, from the engine standpoint alone would demand the time of less than 2 engines. Train schedules are not arranged on this basis, however, and 7 engines would be required under the present schedule or slight modifications thereof. These would be operated by 21 motormen.

A peculiarity exists in the western service of the Illinois Central and all the service of the Wisconsin Central. The line turning west at Sixteenth Street is required to reach a 20-foot elevation before getting to Michigan Boulevard. The original plan provided for a grade beginning north of Twelfth Street, placing the track just east of the train shed and just above the track level at the shed and gaining the elevation by a 2% grade on a curve leading from the east side of the tracks at Twelfth Street to the west side of the tracks and headed west at Sixteenth Street. This did not prove satisfactory, so passenger trains now start from the shed and make the old roadway by about a 3% grade on a sharp curve. This generally requires the services of a pusher engine. An electric engine would save this expense, but what is probably better still, the greatly cramped quarters of the present Twelfth Street Station would be made ample for years to come by double-decking the shed and sending the west-bound trains out from the second floor, doing away with the present grade for passenger business.

The advantages of electric traction for through passenger traffic are largely covered under the head of general aspects. Summarized, they are:

1. Freedom from smoke.
2. Economy of coal.
3. Better control.
4. Greater acceleration.
5. Better efficiency in stopping and starting, economy included.
6. Greater pulling capacity.
7. Greater speed.
8. Greater economy under a varying load factor.
9. Lesser upkeep on engine.
10. A shorter schedule.
11. Lesser engine-ton mileage.
12. Lesser dead runs for engine.
13. Lesser round-house cost.
14. Lesser storage track required.
15. Greater uniformity of efficiency in stormy weather.
16. The suburban service being electrified other services on the same track should be.
17. Greater use of the Twelfth Street station.

Against it would be:

1. The greater fixed charge.
2. The trouble of changing engines at, say, Flossmoor, Kensington, and Riverside.
3. The trouble of readjusting the runs and the general methods.
4. The uncertainty relative to electrifying the freight terminals and the disadvantage of two kinds of traction in the terminal zone.

The first point is discussed elsewhere.

The time lost in changing engines at the margin of the terminal zone would be quickly recovered.

Nos. 3 and 4 are probably the controlling objections at the present time. That officials trained in locomotive traction, and masters of their business, should hesitate to embark in another, even that they should distrust their own judgment as to another, is but natural.

Perhaps no better summary of the entire question can be found than the experience of the New York Central, and this in spite of the fact that their equipment was planned to carry a passenger and freight load, and up to the present moment the road is using only its passenger service to earn fixed charges.

SUBURBAN SERVICE OF THE ILLINOIS CENTRAL RAILROAD

The suburban service runs from Randolph Street on the north to Flossmoor on the south, with three spurs now in operation and a fourth just ready to begin. The western service leaves the main line near Sixteenth Street and runs to Addison, a distance of 25 miles. There are but four trains a day over this line, making it a local rather than a suburban service.

The remaining services now in operation use four tracks to Sixty-seventh Street, 8.4 miles, except from a point just south of Van Buren Street to a point at Randolph Street, .83 miles, where there are two tracks, and a short neck at Randolph Street where use is made of but one track. The two east tracks are reserved for an express service running to Hyde Park, 6.57 miles. All four of these tracks are exclusively suburban in every division of their service.

We have not been able to get a financial statement of this service. We understand that the Interstate Commerce Commission has requested it and that the officials have it. It should be easily determinable, since its earnings are kept absolutely separate and its operation and upkeep is rarely joint with any other arm of the Illinois Central service.

Southeast of Sixty-seventh Street there is a two-track line, 4.51 miles to South Chicago. This track is also used for freight. From Sixty-seventh Street to Blue Island Junction, 6.74 miles, there are two suburban tracks not used for other purposes. From Blue Island Junction to Blue Island, 3.83 miles, is a single-track road used for all purposes. The suburban service is continued over the four-track system to Calumet Junction and then over the two-track system to Flossmoor, 24.92 miles from Randolph Street.

The Kensington & Eastern will run an electrically-hauled suburban service from South Bend through Gary to Kensington, where it will,

Courtesy Westinghouse Electric & Mfg. Co.

Spokane & Inland Empire System — Single-Phase Locomotive, Used for Hauling Freight.

for the present, transfer passengers to the regular Illinois Central service.

The table of train movement before given shows the amount of service given on these different lines. These services can be advantageously studied separately.

The Woodlawn service is local. It is usually done with two-car trains with side-loading doors. There is a train out every five minutes during the rush. The service is every twenty minutes at the laxest times. There is no service from midnight to the early morning. In this service under locomotive traction there are six elements of bad economy.

1. It piles up cars, locomotives, and crews down town in the morning and outside in the evening. The Randolph Street yard cannot stand much of this so there is a good deal of dead hauling. Were the locomotives eliminated and the cars hauled as multiple-unit electric trains, space would be saved and dead hauling would be lessened.

2. Locomotive crews are paid by the mile and are given a certain number of miles a day. This sends an engine over different suburban divisions of the road and means ineffectiveness and interest-charge loss on a locomotive engine under steam.

3. To haul a two-car train with a locomotive engine is uneconomical.

4. Electric traction would permit of greater frequency of trains during all hours of the day.

5. The efficiency of the single track just south of Randolph Street gauges the efficiency of all suburban tracks from the terminal at the north to a south point about Twelfth Street. Locomotive traction impairs the efficiency of this single track.

6. North of Thirty-first Street the neighbors do not contribute much to the support of the service north of them. Douglass and Oakland are moderate contributors. From Forty-third Street to Sixty-third Street is the cream. The dirt and noise of the railroad has prevented a proper development of the residence use of the first two thousand feet back from the lake. If this were clean country, its residence use would increase. The rich Forty-third Street patronage and in lesser measure that of Forty-seventh Street is now being divided by the electric traction of the street and elevated lines. Into the productive country between Forty-seventh Street and Fifty-seventh Street some competition will come unless improvements in service forestall it. The competition at Sixty-third Street is sharp. A better service would add a few blocks to the radius of availability of the trunk line and build a better clientele for the feeders.

This part of the Illinois Central suburban service is in reality a local transportation service. It has demonstrated the potentiality of a railroad to determine the direction of growth of a city. Its patrons are not guided by time cards. As a street-car service it must conform to the operation methods of a local-transportation service or go into the scrap-heap according to the laws of economics.

Local transportation passed through horse-traction, dummy-traction (locomotive), cable to electricity, and every step was demonstration. It is not expected that the Illinois Central will experiment with the cable.

This local transportation discharges fewer passengers into the heart of the city during the rush hours than does either of the electrically operated elevated roads. Everything which it could do to develop the residence use of the lake shore would be to its profit.

Suggestions here offered are electric traction, surface feeding electric lines, more frequent trains, and a connection with a subway distributing system in the down-town district.

What might be termed the radiating systems from Sixty-seventh Street are suburban services. South Chicago is largely self-contained and in consequence does not support a service into the city proportionate to its population. Yet to put this line on the basis of a suburban electric line with a proper feeding system will develop the region and the patronage of the road and will give the same economics of administration that suburban electric lines always give in competition with locomotive traction.

The Flossmoor service is now brought in competition with electric traction and must therefore give equal service or suffer. The Blue Island service must go to electric traction to compete with the shorter haul of the Rock Island. Over none of these lines do the trains make sufficient speed to require the most rigid type of construction. Therefore a third-rail or catenary construction will probably not be required on any except the Flossmoor service and the Kensington & Eastern.

For the economics of ordinary operation of this service we do not think it necessary to say much. The figures of Mr. Brinckerhoff, who was in charge of the South Side Rapid Transit, show that the cost of operation of that line under electricity fell to 8.9 cents per car mile as compared with 10.5 cents under steam-locomotive traction.

The economics of such a service are well understood by the general public as well as by railroad officials. It is safe to say that were it not for the other arms of their service the Illinois Central would have electrified this arm a long time ago. Demonstration of the economics of through passenger business in the heavy trains necessary for economic locomotive traction has only been demonstrated on a large scale in the last few years. The upkeep of an electric service operated in addition to a steam-locomotive service is heavy.

The Port Huron tunnel electric service was not satisfactory so long as there was any use of steam-locomotive engines. The cost of equipment and of maintenance for one arm alone will be disproportionate as compared with its proportion of equipment and maintenance of the three-armed service.

We are convinced that in terminals electrical working of each of the three arms is feasible and economical, and there is no longer reason for the use of locomotive traction on suburban and local-transportation service. Besides, it kills the goose that lays the golden egg.

THE FREIGHT SERVICE

The Illinois Central and its associated lines haul most of their freight to a freight-yard extending from Randolph Street on the south to the Chicago River on the north, and from the old Randolph Street Station on the west to the lake on the east. This yard is used jointly by the four roads, each having certain districts and certain rights within it.

It is occupied by warehouses, elevators, team-tracks, coal-yards. There is a large switch-yard for the Illinois Central at Fordham, a storage-yard at Burnside, a Michigan Central yard at Kensington and a small freight-yard near Riverside and one at Wildwood. In addition, there are many milk-platforms, team-tracks, coal-yards, storage-tracks, and spurs to industrial plants along the right of way. The usual arrangement is a diverging track giving off loading and storage tracks parallel to the original track. Except for a quarter-mile west of State Street on and near Sixteenth Street, it is very free from crossing-tracks which would render the physical problems difficult. The trains are made up by the usual type of switch-engine and they are then hauled away in heavy units. The freight trunk-tracks are used exclusively as such for several miles out, so that the road is relatively free from detention of second and third class trains within the inner part of the terminal zone. The freight-trunks are most heavily loaded at night. During the day hours they are fairly free from traffic, except for cars running between the different yards. Switching and spotting is done mostly during the early hours of the morning and quite considerably during the remainder of the day hours. It will be noted that the peak-load on trunk-line freight is at night, switching in the very early morning and at midday; passengers from 7 to 9 A. M. and 4:30 to 6:30 P. M. A common power-plant, then, would find its load distributed throughout the twenty-four hours. Short intervals of light load could be used to store power for the different peak-hours.

The heavy use of engines by the through passenger traffic will be in the morning and afternoon, by the freight trains at night. The engines can be used interchangeably for freight and passenger use. The suburban cars will run without locomotives. They will be multiple units.

GENERAL CONSIDERATIONS

In considering the electrification of the Illinois Central, electrification should be carried to the end of the suburban zone — that is, all trackage between South Water Street and Flossmoor, (24.92 miles south) should be electrified. The double-track branch from Sixty-seventh Street to South Chicago, and the single-track branch from Blue Island Junction to Blue Island, should be included.

The electrification should also be carried out on the Freeport division to Harlem Junction, where the Wisconsin Central trains reach the Illinois Central right of way.

Preferably, the Michigan Central's trackage should be electrified to near city limits. The exact point we have not determined. They might turn their trains over to electric engines or inaugurate an electric through and suburban service from Hammond. Perhaps an electrification to the heavy industrial zone of the east would pay.

In Plate A (prepared by the staff of the Smoke Department) is shown a representation of the daily train movement over the Illinois Central trackage. This does not include the Freeport division nor any trains belonging to foreign roads after they have left the Illinois Central right of way. It embraces simply the traffic between Randolph Street (or Twelfth Street) and Flossmoor, Blue Island and South Chicago.

The Smoke Department and ourselves made a 24-hour observation of the Illinois Central, with observers stationed at Thirty-ninth Street. They counted the number of trains passing that point during 24 hours, the number and character of cars to each train and estimated the number of passengers in the case of suburban trains. Using this to work from, we have prepared a diagram, Plate B. This gives at A the number of trains on the line at each particular instant of the day, the lines B and C representing the north and south bound trains respectively, going to make up this diagram. From our observed data and from assumptions made on schedule trains not under observation, (these being the trains on the Freeport division and the trains between Fordham and Flossmoor) there was computed the tonnage diagram D, which shows the ton miles per minute being hauled over the road at each minute of the day, the north and south bound components being shown at *E* and *F* respectively.

From this, and after a selection of the probable watt-hour consumption for the different classes of trains, there was computed the diagram *G*, which gives the expected load at the power-house from the operation of the Illinois Central. In this computation we have used a much heavier suburban equipment than the Illinois Central uses. It is probable that the larger proportion of the suburban equipment could be fitted with motors and adapted to an electrical service, but we have preferred to use the New York Central weights as representing the most progressive equipment.

In Appendix *A* are given the detailed calculations whence these curves are plotted.

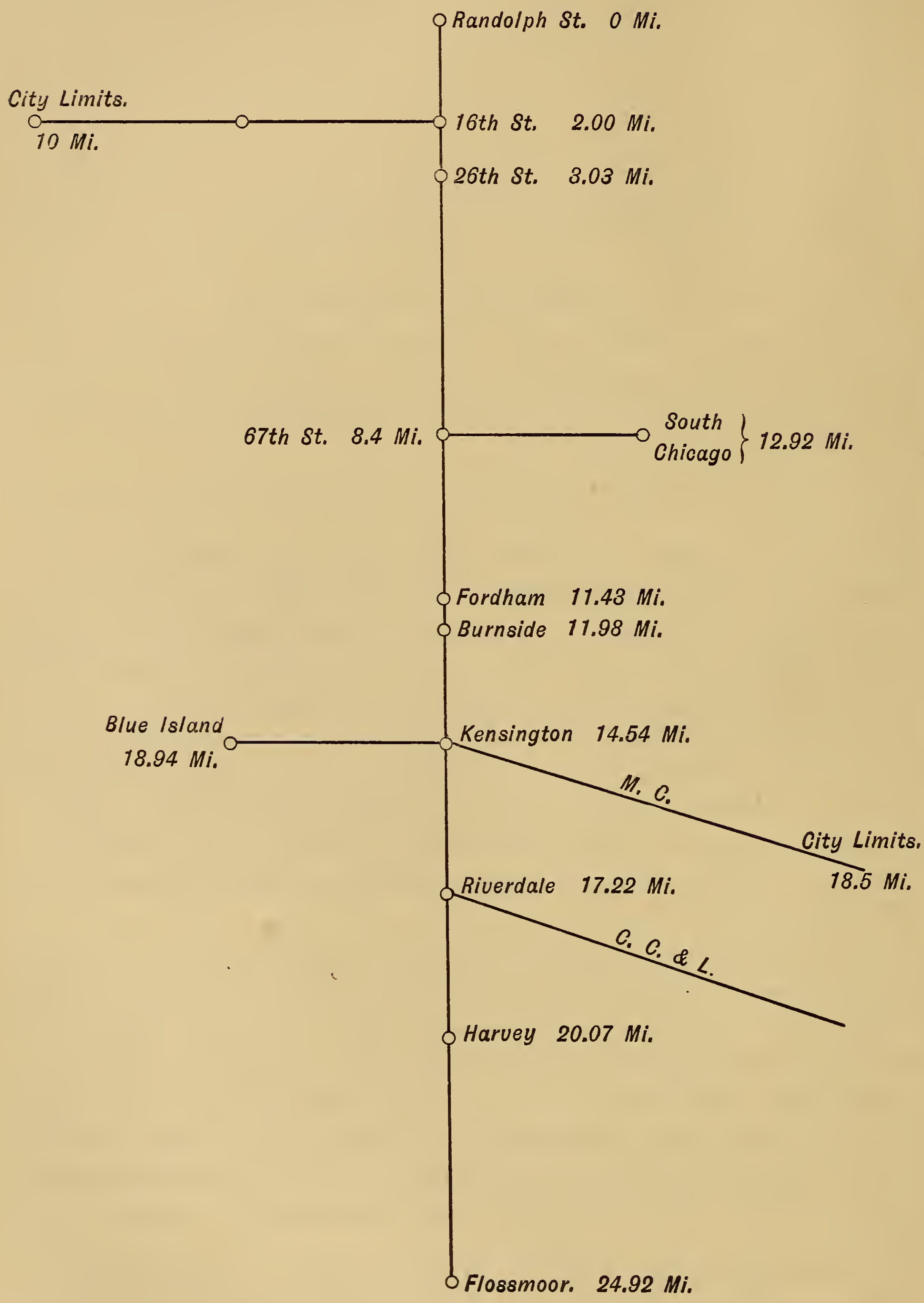
Appendix *B* gives the detailed observations upon which the computations were based. From these we find the following results:

The Illinois Central has, 3,428 scheduled suburban train miles daily, 1,315 scheduled suburban train miles Sunday, 1,054 scheduled daily train miles passenger, 607 scheduled daily train miles freight.

On day observations were taken, 6,435.45 observed and estimated train miles. 2,656,435 observed and estimated ton miles. 103,288.50 estimated kilowatt hours. 413 tons, average weight train. 40 watt-hours per ton mile. 16.05 kilowatt-hours per train mile. Maximum kilowatts 12,300, average kilowatts 4,303.6, minimum kilowatts 700, 35% load-factor.

In computing the probable cost of the electrification of the road, we have made no provision for the purchase of a power-station, since we assume that current can be purchased locally from power-supply companies for seventh-eighths cent a kilowatt-hour, or under. If this cannot be done, the railroad could put in a 12,000-kilowatt plant, which would supply current at that figure. We have allowed in our estimates a manufacturing cost of four-tenths of a cent, which is easily attainable around Chicago, with a large plant, and our estimates on this were as follows:

Power costs about $.004 per kilowatt hour at switchboard (see works cost of power in "Notes on Economics"). Station, complete, costs $90 per kilowatt. Assume 35% load factor. Then we must earn carrying charges upon $257. Allow 3% to sinking fund, 5% interest


Randolph St. 0 Mi.
City Limits.
10 Mi.
16th St. 2.00 Mi.
26th St. 3.03 Mi.
67th St. 8.4 Mi.
South Chicago 12.92 Mi.
Fordham 11.43 Mi.
Burnside 11.98 Mi.
Blue Island
18.94 Mi.
Kensington 14.54 Mi.
M. C.
City Limits.
18.5 Mi.
Riverdale 17.22 Mi.
C. C. & L.
Harvey 20.07 Mi.
Flossmoor. 24.92 Mi.

1% taxes, 3% emergency replacement fund; a total of 12% or 1% a month.

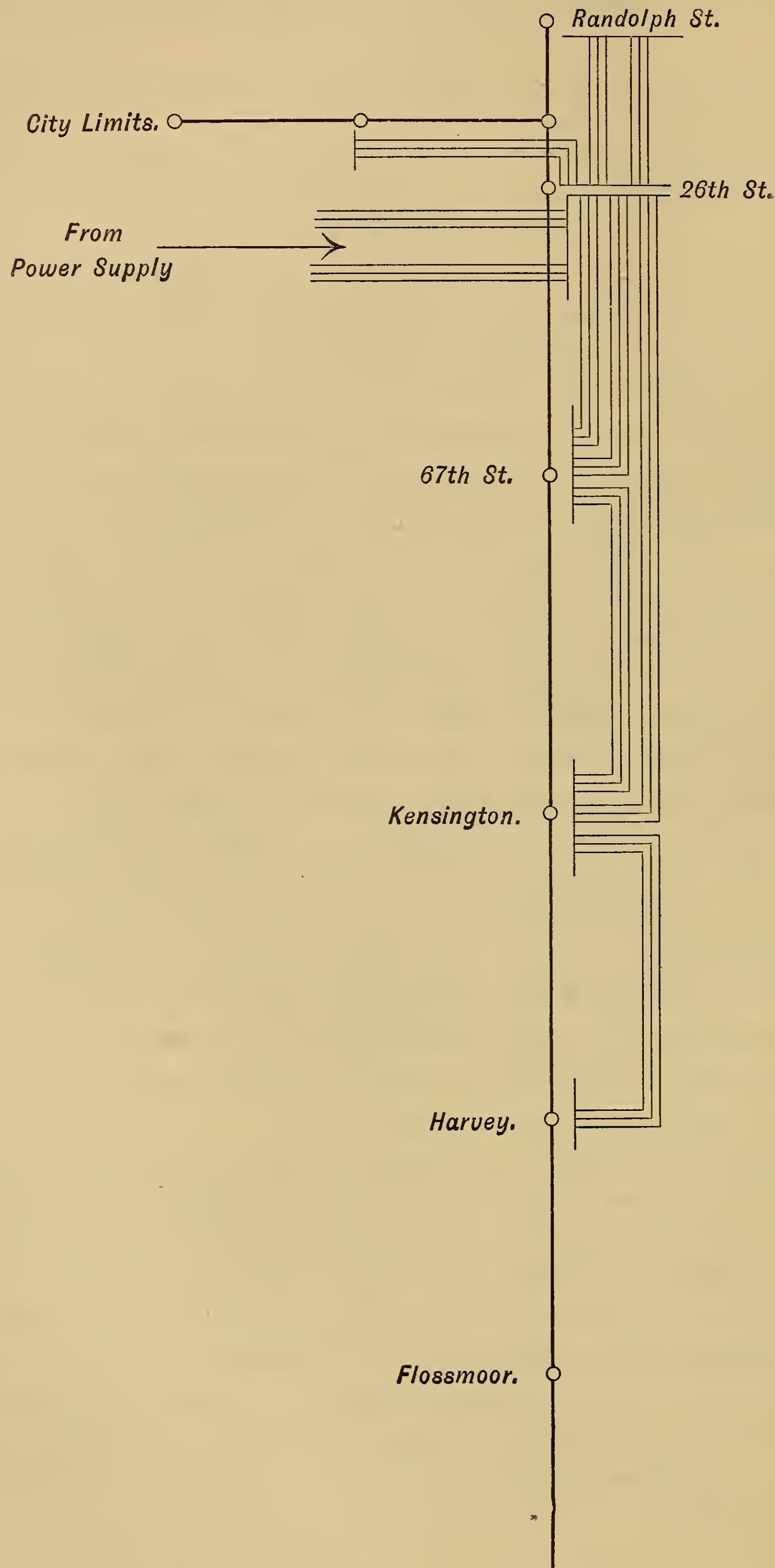
Carrying charges on 1% of $257 = $2.57 per month for 730 hours, or $.0035 per kilowatt-hour.

Manufacturing cost	$.004
Fixed charges	.0035
Total cost	$0.0075 per kilowatt-hour.

Or, if power cannot be purchased at ⅞ cents per kilowatt-hour, it can be manufactured within that figure.

In the electrification of the road, we have assumed that the power would be purchased and delivered to a distributing station at Twenty-sixth Street, whence it would be carried to sub-stations located at Randolph Street, at Sixty-seventh Street, at Kensington, and at Harvey, and about four miles out on the Freeport division. (See diagram) We have assumed that the entire route-trackage would be equipped with a third-rail system and that the greater part of the freight-yards at the terminal and of the trackage in the vicinity of the Twelfth Street station would be equipped with third rail. Above South Water Street, we have assumed that an overhead construction would suffice, generally, of a double-track trolley construction carried by span-wires. The load would be light on these tracks and there would never be occasion for speed. The team-tracks and other tracks to the east of the Wisconsin Central freight-house would also be provided with an overhead trolley equipment, as would the tracks upon the pier at Twelfth Street. We have also assumed that an overhead equipment would be provided to the Twenty-sixth Street round-house and for the sidings below Sixteenth Street. Where intricate track lay-outs demand it, allowance has been made for special overhead work.

For important points a good steel overhead construction with a bar conductor would have to be provided, but for lightly used tracks a section of trolley wire carried overhead would suffice to get trains onto a section of third rail, should they stall. Between electrical efficiency and economy of construction at most points demanding special overhead construction the choice should be to the latter. As the movements are slow therein, we have assumed that an overhead construction can be installed for the Fordham, Burnside, and Wildwood yards. We have assumed a multiple-unit equipment for suburban service. The detailed estimates follow:


Randolph St.
City Limits.
26th St.
From
Power Supply
67th St.
Kensington.
Harvey.
Flossmoor.

A maximum of 34 trains on the line at one time (6:10 P. M.,) 9 of which would be drawn by locomotives and 2 are Woodlawn two-car locals.

A maximum of 115 coaches at this time on suburban. A maximum of 73 motor cars at this time on suburban required. (3 x 23 + 2 x 2.)

Allow 90 car equipments at $5,000 = $450,000.

Assume a 12,000-kilowatt equipment of sub-stations.

Since apparatus will carry 50% overload for two hours, this allows one-third of the apparatus to be down for repairs and the apparatus will still safely carry the peak.

The main power-station, or a distributing and sub-station would preferably be located at Twenty-sixth Street.

Sub-stations may average about 8 miles apart. No part of the line may be much over 4 miles from the sub-station feeding it. Sub-stations actually apart 6.0, 8.4, 6.14, and 5.53 miles.

Greatest distances fed:

4.2 miles, Douglas; 3.00 miles Springfield division; 3.20 miles above Forty-third Street; 4.52 miles South Chicago; 3.07 miles between Fordham and Burnside; 4.44 miles Blue Island; 4.00 miles, Michigan Central; 2.77 miles, just below Riverdale; 4.85 miles, Flossmoor.

Sub-stations cost about $40 per kilowatt complete.

12,000 times 40 = $480,000 for sub-stations.

There must be a distributing station at Twenty-sixth Street.

12,000 times 10 = $120,000 or $600,000 for distributing and sub-stations.

Provide a separate transmission line for each sub-station, tying in the Kensington line to the Sixty-seventh Street station and the Harvey line to the Kensington station, thus permitting of the sectionalization of a section without affecting the remaining ones.

SINGLE TRANSMISSION LINE PER MILE

18 steel towers, 2,000 pounds each, at $0.06 erected	$2,160.00
54 33,000-volt insulators, at $0.55	29.70
30 pounds wire for ties, at $0.25	7.50
Sleeves, solder, etc.	10.00
Extras, curves, etc.	100.00
Wire, 3 miles, No. 2 B. & S., at $0.255	815.00

Labor $100 per mile	$100.00
18 Tower fda (3 cu. yds. at $9.00)	486.00
	$3,708.20
Engineering at 10%	370.80
Total	$4,079.00

DOUBLE TRANSMISSION LINE PER MILE

18 steel towers 2,500 pounds at $0.06 erected	$2,700.00
108 33,000 volt insulators at $0.55	59.40
60 pound wire ties	15.00
Sleeves, solder, etc	20.00
Extra, curves, etc	100.00
Wire, 6 miles, No. 2 B. & S.	1,630.00
Labor, $100 per mile of 3 wires	200.00
Tower fda (4 cu. yds at $9.00)	648.00
	$5,372.40
Engineering	537.25
Total	$5,909.65

Single line, Freeport division	5.03 miles
Single line, Twenty-sixth to Sixty-seventh Street	5.37 miles
Two single lines, Sixty-seventh Street to Kensington	12.28 miles
One single line, Kensington to Harvey	6.40 miles
	29.08 miles

For the entire transmission system, the cost will be:

Double line, Twenty-sixth Street to Sixty-seventh Street	5.4 miles
Double line in conduits Twenty-sixth Street to Randolph 10,000 feet.	
5.4 miles of double line at $5,909.65	$ 31,912.11
29 miles of single line at $4,079.00	118,291.00
10,000 feet "double" in conduits at $4	40,000.00
Total	$190,203.11

For the line construction the following quantities were taken off maps of the road in a running estimate designed to be approximate:

Third Rail Feet	Third Rail Track Feet	Jumper Feet	App. Blocks	Single Trolley Feet	Double Trolley Feet	In Bldgs Feet	Cost of Overhead Work
To Park Row.							
9,175	9,225	280	29				
9,100	7,100	475	30				
16,100	16,550	465	35				
19,000	19,225	520	41				
11,950	12,100	470	38				
9,575	9,225	470	39				
10,650	10,800	585	45				

5,850	6,650	34,500	35	9,250	18,325	5,682	$6,650
16,450	16,525	730	58				10,000
16,600	16,450	910	70				
21,500	21,075	840	93				
14,900	14,925	1,270	183				7,000
160,850	159,850	41,515	696				
To 16th Street				5,675	15,175		
7,350	7,350	480	79				
22,725	22,750	520	69				
18,500	19,200	1,450	184				
14,825	14,825	640	91				
18,100	18,100	180	23				3,000
81,500	82,225	3,270	446				
To Flossmoor.							
36,012	36,012	640	101				
22,220	22,496	340	44	13,800			
18,600	18,930	500	52				
31,600	32,310	200	24	4,000	12,800		
26,300	26,580	700	56				
111,250	111,798	500	30	800			
22,920	22,920	400	42	1,600			
34,900	35,112	2,300	52				
28,200	29,412	11,500	60				
100,692	100,992	1,800	104				
36,700	37,056	1,800	104				3,000
600	600	2,200	48				2,000
44,500	44,864	1,100	42				2,000
80,800	81,656	2,800	44				
595,294	600,738	16,780	803				
South Chicago Branch				16,565	24,100		
Blue Isl. Branch				12,851	20,492		
837,644	842,813	61,565	1,945	64,541	90,892		$33,650
62,000	65,367	3,720	150	8,585			3,000
1,600	1,884	100	10	70,000			
901,244	910,064	65,385	2,105	143,126	90,892	5,682	$36,650
Fordham, Burnside, Wildwood Yds 91.88 miles				162,000	162,000		
901,244	910,064	65,385	2,105	305,126	252,892	5,682	$36,650

The estimated cost of the entire electrification, not including a power house is:

901,324	feet, 300,441 yards. 70-pound rail = 10,516 tons at $30 ($28 + $2 for special section)	$315,480
54,616	2-bolt splice bars at $0.15	8,193
	Nuts and bolts for splice	3,273
109,232	Malleable iron bracket and bolt hooks at $0.40	43,694
163,848	Lag screws, at $0.02	3,277
740,000	feet wooden protection, at $40 per 1,000	29,600
110,000	Pairs insulators, at $0.40	44,000
110,000	Extra for long ties, at $0.50	55,000
55,000	Rail bonds, at $0.70	37,500
2,100	Approach blocks, at $4	8,400
	Miscellaneous at $5 per 1000 feet	4,510
		$552,927
	Add 5%	27,647
		$580,574
	Installing 110,000 ties, at $0.35	38,500
	Installing 110,000 brackets at $0.10	11,000
	Installing 901,324 feet rails and protectors at $50 per 1,000 feet	45,066
	Installing 55,000 bonds at $0.40	22,000
	Installing 21,000 approach blocks, at $0.50	10,500
	Distributing material $35 per 1,000 feet	31,540
65,385	feet jumpers and other cable, at $1.80	117,693
		$856,873
901,324	feet track bonding, at $65 per 1,000	58,590
		$915,463
	Engineering and superintendence at 10%	91,546
		1,007,009
305,126	feet = 57.81 miles single-trolley bracket construction at ($2,497 + $363 bonds), $2,860	165,336
		$1,172,345
252,982	feet = 47.91 miles trolley double-track span construction at ($4,966 + $364), $5,330	255,360
	Total Line	$1,427,705
	5,682 feet in warehouses at $0.40	2,373
		$1,430,078
	Overhead work	36,650
	90 car equipments	450,000
	Sub-stations	480,000
	Distributing station	120,000

Transmission line	190,203
35 Locomotives at $30,000	1,050,000
Change in signals, 30 miles at $1,000	30,000
Change in station platforms $20,000	20,000
Total	$3,806,931
Credit 30 locomotives available for use on other parts of the line, at $15,000	450,000
Total cost of electrification	$3,356,931

No credit is given for suburban locomotives as they will have little availability for the rest of the road. Besides, they are generally old enough to have most of their value written off the books.

Results to be anticipated:

Train on terminal burns about 160 pounds of coal per hour at $1.70 13.5 cents per train mile.

Current at ¾c per kilowatt-hour for 16 kilowatt = 12 cents per train mile.

Current at ⅞c per kilowatt-hour for 16 kilowatt = 14 cents per train mile.

Or cost of current is about equal to cost of coal.

103,288.50 kilowatt-hours at 4 pounds of coal = 413,154 pounds.

413,154 pounds = 207 tons coal (not including switching).

6,500 train miles at 160 pounds, 1,040,000 =	520 tons
Allow for switching	80 tons
Say	600 tons daily
Handling 600 tons coal at 50 cents	$300
Allow 5% ash on 600 tons = 30 tons	
Handling 30 tons cinders at $1.00	30
Saving daily	$330

(This allows for operation and repair of fuel stations, fixed charges on same, and dead time and dead movement lost in coaling.)

Illinois Central costs per train mile, $1.27. Only one-half the number of locomotives will be used — suburbans being handled by motor cars — so one-half of renewals and repairs of buildings should be cancelled, or 1.15% of 2.304%. Water supply of .65% entirely saved.

1.15% + .65% = 1.8%.

1.8 × 1.27 × 6,500 = $148.59 per day saved.

Repairs and renewals of passenger cars cost 1.04c per car mile; we should save one-third this, or .35c per car-mile.

Average through train consists of 6 cars.

$6 \times .35 = 2.1$ cents per train mile.

$2.1 \times 1{,}054 = \$22.13$ per day.

Repairs and renewals, locomotives,

8.8% times 1.27 = 10.26 cents per mile.

Electric locomotives at 3 cents.

10.26 — 3 = 7.26 cents net saving per mile through traffic.

$7.26 \times 1{,}660 = \$120.52$.

(The renewals with electrical apparatus will appear in the sinking fund.)

Repairs and renewals of motor coaches (including electrical equipment) = .01 per car-mile.

Repairs and renewals of passenger coaches = 1.04 cents at present.

Therefore, entire locomotive maintenance saved:

10.26 times 3,500 = $441 saved in suburban service on locomotive maintenance.

60 firemen at $2.50 saved = $150.

Savings to be expected, therefore, are:

Locomotive maintenance saved on suburban trains	$441.00
Locomotive maintenance saved on through trains	120.52
Repairs and renewals, passenger cars	22.13
Saving on water supply and repairs and renewals of buildings	148.59
Saving on firemen's labor	150.00
Saving on coal and ash handling	330.00
Saved per day	$1,212.24

$365 \times \$1{,}212.24 = \$442{,}467.60$

Discount same 5% on account less movement on Sunday = $420,344.00 saved per annum,

= 10.5% on $4,000,000,

= 12.5% on $3,356,931.

Deduct

325 miles × $100 per annum for upkeep of line equipment	$32,500
6% on $450,000 for sinking fund on car equipments	27,000
5% on $120,000 distributing station	6,000
5% on $1,050,000 for locomotives	52,500
4% on $480,000 for sub-stations	19,200
4% on $190,000 for transmission line	7,600
Taxes 1% on $3,356,931	33,570
Total debits	$178,370
Total saving	442,467
There is, therefore, a NET saving of	$264,097

Even if no added traffic comes of the electrification, this will pay 7.87% on investment; or will pay 6.6% on an investment of $4,000,-000, should a better construction be adopted.

And this does not include any estimate on the probable earning power of the electrification *per se.*

The estimated cost of $3,356,931 (not including a power-house) represents the lowest probable cost of a sufficient installation. It could probably be reduced by certain economies such as the employment of wooden poles instead of steel towers for the transmission line, or an insulation of the third rail similar to that employed in the North Shore electrification, but such cheapening would not be wise.

On the other hand, such cost could be considerably increased. With a free hand and only the needs of the future in prospect it might even be trebled. What provision for the future would be made would be a matter for decision by the controlling officials of the railroad and purely a matter of policy. We have contented ourselves with allowing for an equipment sufficient only for the present and, to offset the carrying charges thereon, have only taken into consideration the savings to be effected in electrically handling the present traffic with no allowance for the gains from electrification.

The provision of the cheapest satisfactory equipment for a new enterprise has seemed to us to be in line with American railroad policy. Contrary to European practice, the policy in America in railroad building or extension has been to provide the cheapest construction, which would still be satisfactory, until the work begins to carry itself; then to provide for the future. For this reason, on new lines, heavy grades, wooden trestles, sharp curves, hazardous drainage, and the like prevail until earnings begin to come in when the physical condition of the road is rectified. Occasionally, high-grade improvements are put in from the start, although these occasionally defeat their end — notably where the prime physical condition of a single-track road means the wiping out of a lot of capital which has not yet earned itself back when the necessity comes of double tracking. Wisdom would demand a close consideration of future demands in the installation of a terminal electrification; but the giving heed to future demands would also require a looking to the future for a part of the profits. As its simplest consideration, we have preferred to choose an equipment sufficient only to the demands of the present and to look for the returns only from the savings to be immediately expected.

There will certainly be additional traffic, there will be lessened upkeep of buildings and structures, there will be savings from switching and dead movement, not included in the above, there will be greater mileage capacity, the good will of the public — a number of gains not easily computed. A plot of land near the South Water Street freight terminals, suitable for the erection of a warehouse or factory, rents for about $10,000 per annum. Should the Illinois Central not wish to go into the building of terminal storage warehouses, we still believe that a considerable revenue from ground rent would be available, in the case of electrification.

Should their trains be worked electrically, there is no doubt but that business men contemplating the erection of warehouses, would be willing to construct multi-storied warehouses on the ground occupied by the freight-houses, providing a lower floor for use as a railroad freight-house and paying the railroad handsome ground rent for so convenient a location for their place of business. Without covering over any tracks, the ground now occupied by freight-houses, so used when electrification would allow of it, would afford the railroad its present freight-house capacity and afford 25 warehouse building-sites for which a rental of $250,000 per annum may be expected.

Electrification for the Illinois Central will then not only produce sufficient saving to provide for ample sinking funds and return an income upon the investment, but will probably lead to largely increased returns from operation and open very promising avenues of income whence large amounts of money may be secured. It will effect, outright, savings sufficient to make it worthy of consideration. It offers potential gains sufficient to compel its consideration.

Electrification for the Illinois Central having been found to be practicable as an engineering work, and having been found to be economically advantageous, let us pass to our next and final inquiry regarding this road.

THE FINANCES OF THE ILLINOIS CENTRAL

The object of this inquiry is to determine whether electrification of the Illinois Central terminals would be an unreasonable demand from the financial standpoint.

The studies antedating this have proven that the improvements would save enough on operation to pay enough to cover depreciation and interest charges.

In addition, there is every reason to anticipate still further gains accruing from increased use of tracks, increased business handled and greater value to terminals and especially warehouses and depots. It will be noted that a line of demarcation is drawn between demonstrable earnings and gains which are probable but which still are speculative. Wandering a little further afield, there will be gains from a change in the character of the neighborhoods traversed. We will agree that for purposes of suburban traffic locomotive traction blights a certain amount of residence property on either side. The close-by residence ground along electric lines is more remunerative to the traversing lines. Still other speculative gains come from the good-will of the neighbors, of the community at large, of the press, and, by no means least, of the passengers hauled, both through and local.

But all of these gains might be apparent to the Board of Directors of a railroad and the project still might not be feasible to them or their property because of the general financial condition of the country or because of the finances of their company. The first of these need not be considered in this instance. The country will have resumed its normal financial condition before actual payments on electrification shall be required. The question then resolves itself into this: Has the Illinois Central now the money on hand to pay for such an improvement? If not, can it secure this money at a rate of interest which will not be prohibitive?

Let us compare the Illinois Central with the Northwestern. Perhaps this is especially appropriate as the Northwestern is planning new Chicago terminals to cost many times as much as will electrification.

	Northwestern	Illinois Central
Mileage	7,623	4,378
Total capital stock	$121,998,900	$ 95,040,000
Total funded debt	164,214,000	154,894,270
Capitalization	286,212,900	249,934,275
Capitalization per mile single track	37,500	57,200
Gross earnings	68,878,931	56,610,633
Percentage of gross for dividends based on 10-year average	22.4%	19.5%
Ton mileage per mile ('06)	694,047	1,408,403
Passenger mileage per mile ('06)	94,653	115,598

During the last ten years the Northwestern road has earned nearly $486,000,000 gross, of which it has had left after charges nearly $109,000,000 for dividend, betterment, and reserve purposes. Before bringing down net earnings the road has spent about 23%, more than $110,000,000, for maintenance and upkeep, and this amount has been sufficient to add very materially to the uncapitalized value of the plant, besides maintaining the property free from impairment. Since 1900 the increase in gross earnings has aggregated 81½ %, but capitalization has increased only 26.6 %.

In ten years, the Illinois Central has earned about $406,000,000 of which about $89,400,000 has been available for dividends after very liberal maintenance.

In 1907, the Illinois Central earned $12,952.10 per mile and expended $8,659.28 per mile. The net earnings were 33.57%. The rate paid to the stock-holders was 7%, the difference going to various funds presently to be discussed.

From 1855 to 1907, the Illinois Central paid the stock-holders $138,362,061.59 in cash dividends. They paid the state of Illinois $25,604,397.99 as 7% on the gross earnings of 705.5 miles of track.

The road has paid 45 dividends since 1863. It has never passed a dividend. The average rate for 45 years has been 6.922%.

This high interest rate is not usual except in properties subject to a high rate of hazard. Such, however, is not the case here. Everything connected with the road makes for stability. It runs from east to west and from north to south. It therefore handles an unusual variety of crop products. A short corn crop is apt to be balanced by a good cotton crop. The history of financial and economic depressions, certainly in the last fifty years, does not show synchronism between periods of depression north and south.

In addition, the Illinois Central provides rather unusually against depreciation and spends quite liberally for upkeep. The table shows a percentage of dividend disbursement to gross of 19.5 as against 22.4 for the Chicago and Northwestern. In 1907 the Illinois Central passed to its various funds to insure against losses of one sort and another $8,257,234.93 as against $6,652,800.00 for dividends. This might, in a certain sense, be termed a surplus dividend fund. In addition, they passed to maintenance of way $6,851,449.77, and to maintenance of equipment $9,596,006.84. The fund to secure against losses includes $3,794,986.97 for the improvement fund and $192,946.64 for the permanent improvement fund.

If these figures be compared with the figures, mileage, liability, maintenance charges, reserves, and dividends of such standard, reputable, high-grade roads as the Chicago & Alton, and the Rock Island, it will be seen that the Illinois Central is well within its bonding capacity.

In addition to these features of stability, the road is actually double-tracked for 678.53 miles and is potentially double-tracked between Chicago and all of its great markets except Omaha. This double-tracking, and other permanent improvements, have been done partly out of bonds but largely out of earnings, so that the increase both in earning value of the property and in its physical assets has been out of proportion to the increase of its funded debt and stock liability. Some of the moneys that they might have paid as cash dividends have been passed to the account of dividends through greater security.

For example, they have just secured entrance to Birmingham in great measure by trackage arrangement with the Mobile and Ohio, K. C., M. & B., and North Alabama, yet they have built 83.23 miles. The cost of this venture is $4,380,000, of which the sum of $1,120,000 is spent in the Birmingham depots and terminals. The Memphis plan now being executed calls for an expenditure of $3,000,000.

The above figures do not include the data relating to the Yazoo and Mississippi Valley owned by the Illinois Central.

The construction of the Kensington & Eastern is being financed, and the operation of the Indianapolis Southern is being carried on, in order to originate and develop both a new passenger field and a new kind and volume of freight. The wisest of expenditure for double-tracking, bridges and other items is going on, and yet the only adverse (if it might be so termed) indication of this in the 1907 report is a net liability account of $10,000,000. On January 1, 1908, they filed with the United States Trust Co. of New York a first lien equipment mortgage to secure a bond-issue of $30,000,000 bearing 4%. Poor's Manual for 1908 contains no reference to this loan, but does contain notice of an authorization of increase of capital stock in the sum of $28,512,000. Of this $14,256,000 was offered to the stockholders of record, May 28, 1908. Provision was made for the issuing of the remaining half of the authorization according to the demands of the road. The general balance sheet carried two items that probably this stock-proceeds would be used to settle, namely, net liabilities $10,968,135.37 and profit and loss $4,160,960.12. It is reasonable to conclude that some of the moneys went for double-tracking, some for Memphis and Birmingham and similar improvements, and some went into advances account of other roads, $7,581,728.72.

However, we cannot figure either of these items, as we have no knowledge as to which of the company's liabilities it has cancelled.

As soon as this money shall be available in its entirety it will easily carry the profit-and-loss account of 1907, such improvements as are now under way, so far as popular information goes, and leave in the treasury far more than the four or six millions required to electrify the Chicago terminals as far out as Flossmoor, South Chicago, Blue Island and Riverside, for freight, passenger, and suburban service. Of this six millions, two millions will be for a power-plant.

If there is any monetary difficulty, power can be purchased on somewhat the same basis as the Michigan Central at Detroit. Therefore, it can be assumed that this two millions will be financially feasible by one plan or the other. It would be most conservative to estimate that any corporation, and especially the Illinois Central, could borrow 50% of the remaining four millions on the improvement as security. This leaves two millions to come from its general borrowing powers. What a bagatelle as compared with its 294 millions of capitalization, or as compared with the difference between its par value and its market value, or between its par value and its earning value, or between its par value and its book value.

But further comparisons are rather useless. It is not much of a hazard that this thirty-million-dollar loan makes the six millions required available at any time without further increase in the funded debt.

THE RAILROADS IN RELATION TO LOCAL TRANSPORTATION

MILTON J. FOREMAN

Railroads doing an intramural passenger-carrying business in Chicago are to all intents and purposes street railways, and should, so far as that branch of their business is concerned, be considered and treated as such.

While it is true that these roads are organized under the "Railroad Act," and not subject, by ordinance, to the same control and regulation by the city as are the surface street-railway lines and elevated railway lines, they have, by engaging in this branch of business, become a part of the local transportation system.

The ordinances under which almost all of the street railways of the city are now being operated practically make the city a partner; it not only shares the net profits, but has a controlling voice in the construction, maintenance, and operation of the roads. To these companies, in which the city has a direct interest, the railroads doing an intramural and local passenger business are direct competitors, and they thereby become competitors of the city of Chicago.

The growth and importance of this feature of the railroad business was apparently overlooked when the railroads were granted the right to enter Chicago, for if it had been foreseen, the city would undoubtedly have specifically reserved control and regulation of that part of their business.

The character of the grants under which these railroads are operated within the city, contains no reservation as to control, regulation, payment of compensation, or rates of fare to be charged in their intramural business, thus putting them in a very much better position than that occupied by the surface and elevated railways engaged in the same business, and they should be required and should be willing at least to adopt and install the same means of propulsion as is required of the former.

Passengers are now carried practically all over the city of Chicago, on the surface street railways, for one five-cent fare. Within the same territory the railroads, without paying any portion of their revenue to the city for the privileges which they enjoy, and disclaiming any right of control or regulation by the city, charge and receive several times this fare for carrying a passenger the same or a lesser distance.

On account of the large area covered by Chicago, and the importance to it of the large population lying just outside of its limits, the development of this form of transportation should be encouraged, as a street-railway system, under proper municipal control and regulation.

The first step in this direction is the electrification of the terminals used in connection with their intramural business. It is my opinion that the practicability and final economy to the railroad companies will lead to the prompt electrification of all their passenger and freight terminals. It will be like the experience the railroads had with track-elevation.

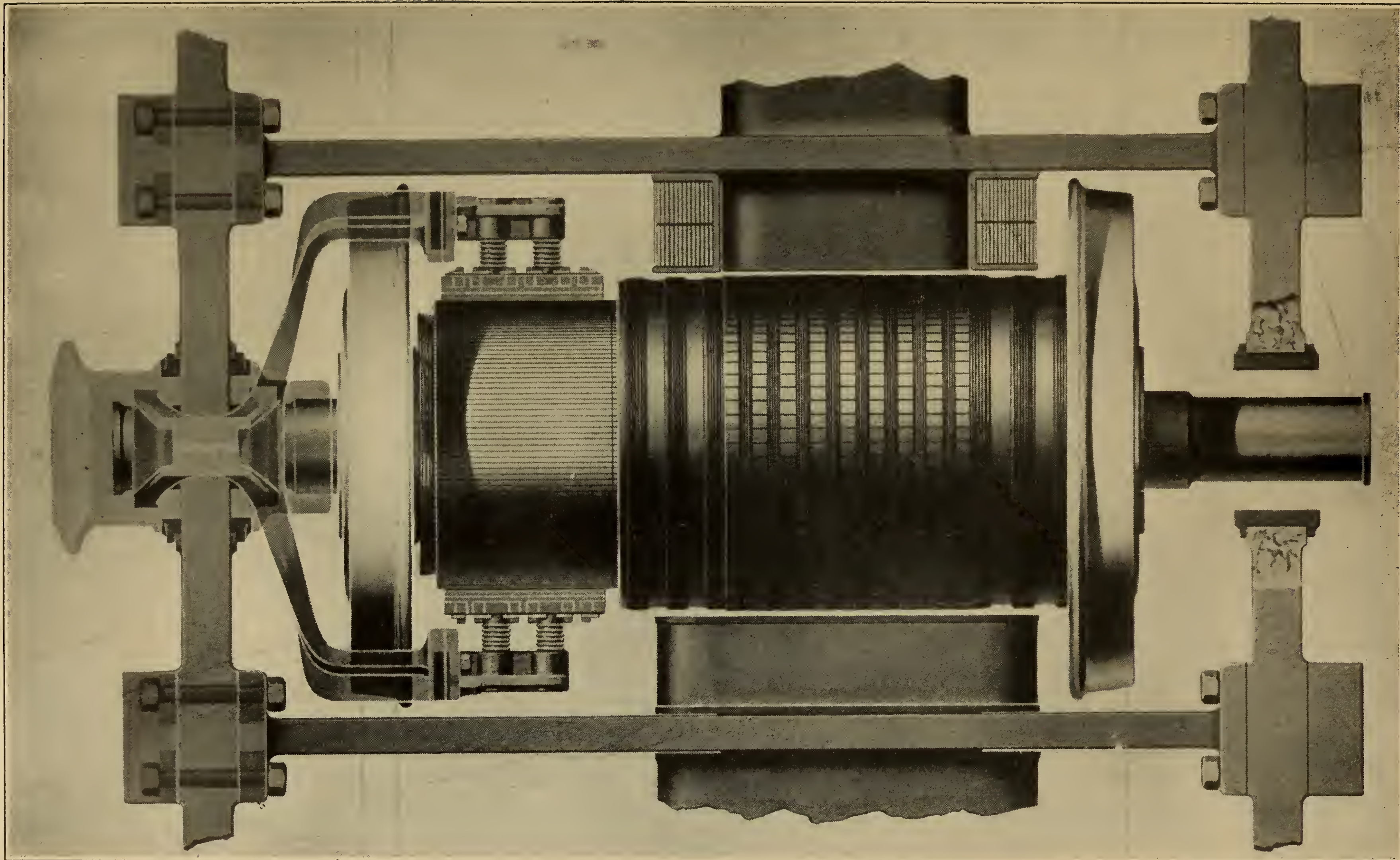
If the railroads want to retain their local business, it is my opinion that they will, in self-defense, be required to electrify and that at once. Many interurban roads are already built, and are now being built to the limits of the city, from all directions, and they are knocking at our doors for admission. These interurban roads tap regions traversed by the railroads, and if the railroads desire to compete with them for Chicago business, they will be compelled to adopt the newest and most modern methods of propulsion. In the event the railroad companies decline to make this change, the city has various methods by which the wisdom of the step may be impressed upon the railroad companies. The city, for instance, might, amongst other things, give the other carrying agencies within the territory traversed by these railroads such facilities as would make it more desirable for passengers to travel upon these lines than upon the railroads.

That the railroads are not oblivious to this trend is proven by the fact that there are cases where they are joining neighboring cities to their trunk lines in Chicago by means of electric lines.

By the electrification of the Evanston division of the C. M. & St. P. railway, this piece of track was changed from a piece of dead property, used for an occasional passenger and freight train, to an electric railway, and the amount of travel on this road has so far exceeded expectations that it has already outstripped the provided facilities.

The change from steam to electricity of course requires money, but this was equally true when the change was made from horse to cable cars, and from cable to electricity. It is equally true in the rehabilitation of the electric street-railway systems now under way, and will be true when, under the existing ordinances, the traction companies are required to install underground trolley.

The railroads operating street-railway lines within the city of Chicago should, so far as possible, be subject to the same regulation and control



Courtesy General Electric Co.

Motor for Electric Locomotives used by the New York Central & Hudson River Railroad.

as are their competitors, the traction and elevated lines, and, as a first step in this direction, they should adopt, so far as their operation within the city is concerned, the most modern means of propulsion, based upon the safety, comfort, health, and convenience of the people of the city.

That means immediate electrification.

CONCLUSIONS

MILTON J. FOREMAN, W. A. EVANS, PAUL P. BIRD, G. E. RYDER,
H. H. EVANS

Our study of the questions discussed in the foregoing pages leads us to the following conclusions:

1. Smoke is injurious to health:
   (a) Directly, by polluting the air;
   (b) Indirectly, by destroying vegetation.
2. It is expensive, because it:
   (a) Increases laundry bills;
   (b) Ruins cloths and clothing;
   (c) Increases cost of painting and washing buildings and other structures;
   (d) Corrodes iron and other metals;
   (e) Disintegrates stone in structures to some extent;
   (f) Darkens the air and necessitates a greater use of gas and other luminants;
   (g) Destroys vegetation;
   (h) Wastes coal;
   (i) Injures Chicago as a market center in that its attractiveness to the out-of-town buyer is lessened.

3. Stationary steam plants can be so constructed and operated as that they can be run practically, feasibly, and economically without making smoke.

4. While it is possible to operate a steam locomotive without making smoke, it is impractical in the operation of a railroad to maintain a smokeless condition of locomotives.

5. Locomotive traction is harmful wherever the volume of business requires the use of a number of engines within a narrow radius.

6. It is not feasible for Chicago railroads to use either coke or anthracite coal for any large number of locomotives.

7. Electric traction would remedy so much of the smoke evil as results from locomotive smoke.

8. Electric traction is a developed art, the experimental stage being well in the past. This applies to:
   (a) Suburban business;

(b) Through passenger business;

(c) Freight business in differing proportions.

9. The Illinois Central locomotives do harm.

10. Electrification of the Illinois Central terminal in its three arms, through passenger, local passenger, and freight, is feasible; because:

(a) The needed funds are available;

(b) Such operation will save the road enough on cost of operation to pay the fixed charges on the added investment and also a safe charge for depreciation;

(c) There will be greater track and train efficiency;

(d) There will be increased use of overhead space;

(e) The physical limitations now crippling the road will be removed;

(f) Their physical track and yard problem is exceptionally simple;

(g) All phases of traction equipment have been demonstrated to a degree hitherto unheard of in the history of traction.

11. In one of its arms the Illinois Central is a part of the local-transportation problem, an active competitor with other local transportation companies, and should be subject to the same opportunities, limitations, and controls.

12. The traction of the different arms cannot be different with a proper regard for the economies.

13. The Illinois Central problem does not differ radically from the problems of the other roads entering Chicago.

14. A proper regard for the conservation of the world's coal supply demands the coal economy of electric traction as compared with that of locomotives.

15. The air is the common property of the people.

16. The right of control of the purity of the air by government is superior to the right of control of water in proportion as the purity thereof is more necessary for life and health than is water.

17. In the reasonable administration of this trusteeship or right, the obligations of government are superior to any rights of property or liberty of any individual or any corporation or government of lesser jurisdiction.

18. The demand that the Illinois Central electrify its terminals is reasonable, is justified by a proper consideration of all the factors involved, and is a duty devolving upon the local government

APPENDIX A

TABULATED CALCULATIONS FOR TON-MILE-MINUTE AND LOAD CURVES FOR ILLINOIS CENTRAL TERMINAL

In these computations the following arbitrary rulings were observed:

All freight trains not on schedule will be assumed to run between Randolph Street and Floosmoor on a schedule time of 1 hour and 45 minutes.

Light engines will be considered as going between Twelfth Street Station and Burnside at a speed of 15 miles per hour (see below).

Michigan Central freights, not on schedule, will be assumed to run between Kensington and Randolph Street on a schedule time of 1 hour and 5 minutes.

Allow 20 minutes for freights to run from Thirty-ninth Street to Randolph Street.

Allow 40 minutes for engines and empty equipment to run between Burnside and Twelfth Street.

Allow 10 minutes on such equipment from Thirty-ninth Street to Twelfth Street.

Allow 1 hour and 20 minutes for C. C. &. L. freights to run between Riverdale and Randolph Street.

Allow 25 minutes Freeport division and W. C. passengers from city limits to Twelfth Street.

Allow 30 minutes for Addison passengers between Randolph Street and city limits.

Allow 35 minutes for Freeport and W. C. freights to run between Randolph Street and city limits.

Figure all Pullman cars to contain 20 people.

Figure coaches to contain 42 persons each, except suburbans.

Figure diners and parlor cars as Pullman cars.

Figure two coaches as containing passengers — the others being counted as baggage, mail, and express. Where a train hauls a chair car, figure its passengers in addition to those in the two coaches.

Assume Addison passenger trains to haul 4 cars each, 35% full.

Where the loading of a freight is not evident, figure:

- All refrigerator cars going north to Randolph Street as loaded.
- All refrigerator cars going south from Randolph Street as empty.
- All coal cars going north to Randolph Street as loaded.
- All coal cars going south from Randolph Street as empty.
- All freights clearly on schedule, if not containing an unusual number of cars as hauling loaded cars.

Freights in doubt at 50% loaded, 50% empty.

Trains of over 40 cars pulled by a single engine as made up entirely of empty cars.

Freight trains not observed as containing 20 cars, 50% of which are empty.

The columns in the tabulation are self-explanatory with the exception of the items C_1 and C_2 p. As a number of runs in the suburban service are identical, a table of values of the ton miles per minute due to the weight of the train and to the weight of the passengers, with all seats filled, was made for each variety of run and for a varying number of coaches from which the values could be entered on the computation sheets with a saving of labor. The values C_1 and C_2 p then represent the following:

Let T = time of run in minutes.

M = miles distance between terminals.

W = total weight of train in tons.

Ton-miles per minute = ordinate = $O = \frac{MW}{T}$

Let W_1 = weight of train alone.

W_2 = weight of passengers.

$W = w_1 + w_2 \quad O = \frac{MW}{T} = \frac{M(w_1 + w_2)}{T} = \frac{Mw_1}{T} + \frac{Mw_2}{T}$

If a passenger weighs 140 pounds

n = number of coaches on train.

p = percentage seats filled.

s = seats per coach.

$$w_2 = \frac{140\ n\ s\ p}{2000}$$

$$O = \frac{M\,w_1}{T} + \frac{M \times 140 \times ns}{T \times 2000} \times p = C_1 + C_2\,p$$

Train No.	Train Classification	Direction of Run	Total Time of Run in Minutes	Ton Miles per Minute: Train C_1	Ton Miles per Minute: Load C_2P	Ton Miles per Minute: Total $C_1 + C_2P$	Total Ton Miles	Miles Run	Time: Leave–Arrive	Observed Time at 39th St.	Estimated Watt-Hrs. per Ton Mile	Total Kilowatt-Hrs. on Run	Kilowatts per Ton Mile per Minute	Instantaneous Kilowatts
1	Pass. M. C. 12th–Kensington	S	34	.....	......	205.32	6,980.9	13.09	12:05–12:39	12.14	40	279.24	2.4	492.77
3	Loc. Sub. Rand. – Flossmoor	S	73	69.19	3.04	72.23	5,272.8	24.92	12:10– 1:23	12.27	60	316.37	3.6	260.03
	Eng. Rand. – Burnside	S	45	.....	......	25.15	1,132.1	11.98	12:21– 1:06	12:36	30	33.96	1.8	45.17
5	Loc. Sub. Rand. – So. Chicago	S	45	59.01	2.60	61.61	2,769.4	12.91	12:30– 1:15	12.46	60	166.16	3.6	221.80
7	Loc. Sub. Rand. – Woodlawn	S	28	59.01	.52	59.53	1,666.8	7.90	12:45– 1:13	1.01	80	133.34	4.8	285.74
	Ft. M. C. Rand. – Kensington	S	65	......	......	298.52	19,403.6	14.54	12:48– 1:53	1.08	20	388.07	1.2	358.22
9	Loc. Sub. Rand. – Gr. Cross.	S	36	52.91	2.32	55.23	1,988.3	9.48	1:00– 1:36	1.14	60	119.30	3.6	198.83
11	Ft. I C. Fordham – Floss.	S	45	......	......	328.11	14,764.8	13.49	1:00– 1:45	....	20	295.30	1.2	393.73
	Equipt. Rand. – Burnside	S	45	54.94	......	54.94	2,472.3	11.98	1:30– 2:15	1.45	40	98.89	2.4	131.86
	Ft. I. C. Rand. – Flossmoor	S	105	......	......	235.79	24,658.3	24.92	1:30– 3:15	1.50	20	493.17	1.2	282.95
	Equipt. I. C. 12th – Burnside	S	40	......	.....	177.04	7,081.6	10.53	1:36– 2:16	1.46	40	283.26	2.4	424.90
	Ft. I. C. Rand. – Flossmoor	S	105	......	......	287.77	30,215.5	24.92	1:04– 3:49	2.24	20	604.31	1.2	345.32
13	Pass. Freeport Div. 12th–I. C.	S	25	......	......	176.04	4,401.1	11.00	2:40– 3:05	.....	40	176.04	2.4	422.50
15	Pass. I. C. 12th – Flossmoor	S	38	......	......	276.27	10,498.1	23.47	2:50– 3:28	2.59	40	419.92	2.4	663.05
17	Pass. M. C. 12th – Kensington	S	30	......	......	117.11	3,513.4	13.09	3:00– 3:30	3.08	40	140.53	2.4	281.06
	Eng. Rand. – Burnside	S	45	......	......	25.15	1,132.1	11.98	4:17– 5:02	4.32	30	33.96	1.8	45.27
25	Loc. Sub. Rand. – Harvey	S	61	96.24	.89	97.13	5,924.9	20.07	5:25– 6:26	5.45	60	355.49	3.6	349.67
29	Loc. Sub. Bl. Is.	S	70	54.94	.97	55.91	3,913.7	18.94	5:50– 7:00	6.07	60	234.82	3.6	201.28
31	Loc. Sub. Rand. – So. Chicago	S	45	59.01	.31	59.32	2,669.4	12.91	6:00– 6:45	6.14	60	160.16	3.6	213.55
33	Loc. Sub. Rand. – Burnside	S	42	132.68	3.51	136.19	5,720.0	11.98	6:05– 6:47	6.21	60	343.20	3.6	490.28
27	Loc. Sub. Woodlawn. – Floss.	S	47	......	......	82.06	3,387.0	17.02	6:13– 7:00	......	60	203.22	3.6	295.42
	Eng. 12th – Burnside	S	40	......	......	24.88	995.1	10.53	6:13– 6:53	6.23	30	29.85	1.8	44.78
37	Ft. I.C. Fordham – Flossmoor	S	60	......	......	328.11	14,764.8	13.49	6:30– 7:30	....	20	393.73	1.2	393.73
39	Loc. Sub. Rand. – Flossmoor	S	74	98.5	1.81	100.31	7,422.9	24.92	6:35– 7:49	6:50	60	445.37	3.6	361.12
44	Ex. Sub. Rand. – So. Chicago	S	35	75.29	1.33	76.62	2,681.7	12.91	7:00– 7:35	7.09	70	187.72	4.2	321.80
	Ft. I. C. Rand. – Flossmoor	S	105	......	......	74.64	7,837.3	24.92	7:03– 8:48	7:23	20	156.75	1.2	89.57
49	Loc. Sub. Rand. – Woodlawn	S	28	59.01	.83	59.84	1,675.5	7.90	7:05– 7:33	7:18	80	134.04	4.8	287.23
51	Pass. M. C. 12th – Kensington	S	35	......	......	148.59	5,200.7	13.09	7:10– 7:45	7:18	40	208.03	2.4	356.62
53	Ex. Sub. Rand. – Bl. Is.	S	55	84.32	.74	85.06	4,678.3	18.94	7:20– 8:15	7:29	70	327.48	4.2	357.25
55	Loc. Sub. Kens. – Bl. Is.	S	13	......	......	67.35	875.6	4.40	7:25– 7:38	.....	60	52.54	3.6	242.46
57	Loc. Sub. Rand. – Woodlawn	S	28	59.01	.78	59.79	1,674.1	7.90	7:25– 7:53	7:40	80	133.93	4.8	286.99

61	Ex. Sub.	Rand. – So. Chicago	S	35	91.76	.83	92.59	3,240.7	12.91	7:40– 8:15	7:48	70	226.85	4.2	388.88
63	Loc. Sub.	Rand. – Woodlawn	S	28	59.01	.78	59.79	1,674.1	7.90	7:45– 8:13	8:00	80	133.93	4.8	286.99
65	Ex. Sub.	Rand. – 67th	S	18	141.47	......	141.47	2,546.5	8.40	7:45– 8:03	7:57	70	178.26	4.2	594.17
	Horse M. C.	12th – Kens.	S	50	......	......	35.74	1,786.8	13.09	7:59– 8:49	8:09	40	71.47	2.4	85.78
73	Ex. Sub.	Rand. – Harvey	S	47	129.43	1.16	130.59	6.137.7	20.07	8:00– 8:47	8:14	70	429.64	4.2	548.48
77	Loc. Sub.	Rand. – Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	8:05– 8:33	8:21	80	69.78	4.8	149.52
79	Ex. Sub.	Rand. – So.Chicago	S	35	111.37	1.49	112.86	3,950.1	12.91	8:20– 8:55	8:31	70	276.51	4.2	474.01
81	Loc. Sub.	Rand. – Woodlawn	S	28	30.74	1.02	31.76	889.3	7.90	8:25– 8:53	8:42	80	71.14	4.8	152.45
83	Pass. I. C.	12th – Flossmoor	S	52	......	......	141.41	7,353.1	23.47	8:30– 9:22	8:37	40	294.12	2.4	339.38
87	Pass. W. C.	12th – I. C.	S	25	......	......	118.10	2,952.4	11.00	8:35– 9:00	.. ..	40	118.10	2.4	283.44
89	Pass. C. C. & L.	12th – Rivdle.	S	40	......	......	83.60	3,343.9	14.77	8:35– 9:15	8:44	40	133.76	2.4	200.64
91	Ex. Sub.	Rand. – Bl. Is.	S	53	73.26	.64	73.90	3.916.7	18.44	8:40– 9:33	8:49	70	274.17	4.2	310.38
	Eng.	Rand. – Flossmoor	S	100	......	......	23.55	2,354.9	24.92	8:41–10:21	8:56	30	70.65	1.8	42.39
97	Pass. M. C.	12th – Kens.	S	30	......	......	166.98	5,009.6	13.09	8:45– 9:15	8:53	40	200.38	2.4	400.75
99	Loc. Sub.	Rand. – Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	8:45– 9:13	9:00	80	69.78	4.8	149.52
101	Pass. Big 4	12th – Flossmoor	S	47	......	......	185.36	8,712.1	23.47	9:00– 9:47	9:09	40	348.48	2.4	444.86
103	Ex. Sub.	Rand. – So. Chicago	S	35	75.29	.66	75.95	2,758.3	12.91	9:00– 9:35	9:09	70	193.08	4.2	318.99
...	......	......	...	...	...	...	...	...	...	......	...	...	...	...	...
109	Loc. Sub.	Rand. – Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	9:05– 9:33	9:20	80	69.78	4.8	149.52
111	Ex. Sub.	Rand. – Flossmoor	S	57	89.54	2.74	92.28	5,260.0	24.92	9:20–10:17	9:28	70	368.20	4.2	387.58
113	Loc. Sub.	Rand. – Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	9:25– 9:53	9:40	80	69.78	4.8	149.52
121	Ex. Sub.	Rand. – So. Chicago	S	35	75.29	1.41	76.70	2,684.5	12.91	9:40–10:15	9:49	70	187.92	4.2	322.14
123	Pass. I. C.	12th – Floss.	S	45	......	......	176.60	7,947.0	23.47	9:40–10:25	9:46	40	317.88	2.4	423.84
125	Add. Pass.	Rand. – I.C.	S	30	......	......	73.00	2,090.1	12.50	9:43–10:13	......	40	87.60	2.4	175.20
127	Pass. Freeport Div.	12th–I. C.	S	25	......	......	178.95	4,473.7	11.00	9:45–10:00	......	40	178.95	2.4	429.48
129	Loc. Sub.	Rand. – Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	9:45–10:13	10:02	80	69.78	4.8	149.52
131	Ex. Sub.	Rand. – Bl. Is.	S	53	73.26	3.22	76.48	4,053.4	18.94	10:00–10:53	10:09	70	283.74	4.2	321.22
135	Pass. I. C.	12th – Flossmoor	S	45	......	......	179.53	8,079.1	24.92	10:02–10:47	10:11	40	323.16	2.4	430.87
137	Loc. Sub.	Rand. – Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	10:05–10:33	10:19	80	69.78	4.8	149.52
139	Ex. Sub.	Rand.– So. Chig.	S	35	91.76	2.07	93.83	3,284.1	12.91	10:20–10:55	10:30	70	229.89	4.2	394.09
141	Loc. Sub.	Rand.– Woodlawn	S	28	30.74	.81	31.55	883.4	7.90	10:25–10:53	10:40	80	70.67	4.8	151.44
	Ft. M. C.	Rand. – Kensington	S	65	......	......	32.32	2,101.0	14.54	10:26–11:31	10:46	30	63.03	1.8	58.18
145	Pass. M. C.	12th– Kens.	S	30	......	......	206.21	6,186.3	13.69	10:30–11:00	10:39	40	247.45	2.4	494.90
	Eng.	Rand.– 39th	S	15	......	......	29.04	435.6	4.61	10:37–10:52	10:52	30	13.07	1.8	52.27
149	Ex. Sub.	Rand.– Harvey	S	47	87.51	3.91	91.42	4,296.7	20.07	10:40–11:27	10:48	70	300.77	4.2	383.97
151	Loc. Sub.	Rand.– Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	10:45–11:13	11:00	80	69.78	4.8	149.52
153	Ex. Sub.	Rand.– So. Chicago	S	35	75.29	3.98	79.27	2,774.4	12.91	11:00–11:35	......	70	194.21	4.2	332.93
157	Loc. Sub.	Rand.– Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	11:05–11:33	11:19	80	69.78	1.2	149.52
159	Ex. Sub.	Rand.– Bl. Is.	S	53	73.26	5.15	78.41	4,155.8	18.94	11:20–12:13	11:29	70	290.91	1.8	329.32
	Ft. I. C.	Rand.– Flossmoor	S	105	......	......	319.08	33,503 9	24.92	11:20– 1:05	11:40	20	670.08	1.2	382.90

Train No.	Train Classification	Direction of Run	Total Time of Run in Minutes	Ton Miles per Minute			Total Ton Miles	Miles Run	Time		Observed Time at 39th St.	Estimated Watt-Hrs. per Ton Mile	Total Kilowatt-Hrs. on Run	Kilowatts per Ton Mile per Minute	Instantaneous Kilowatts
				Train C_1	Load C_2P	Total $C_1 + C_2P$			Leave	Arrive					
	Ft. M. C. Rand.– Kensington	S	65	......	......	25.63	1,665.8	14.54	11:22	12:27	11:42	30	49.97	1.2	46.13
161	Loc. Sub. Rand.– Woodlawn	S	28	30.74	.61	31.35	877.8	7.90	11:25	11:53	......	80	70.22	4.8	150.48
169	Ex. Sub. Rand.– So. Chicago	S	35	75.29	4.65	79.94	2,797.9	12.91	11:40	12:15	11:50	70	195.85	4.2	335.75
171	Loc. Sub. Rand.– Woodlawn	S	28	30.74	1.62	32.36	906.1	7.90	11:45	12:13	12:00	80	72.49	4.8	155.33
173	Ft. Freeport Rand.– I. C.	S	35	......	......	301.61	10,556.3	12.50	11:45	12:10	......	20	211.13	1.2	361.92
175	Ex. Sub. Rand.– Flossmoor	S	57	109.12	5.88	115.00	6,555.0	24.92	12:00	12:57	12:08	70	458.85	4.2	483.00
179	Loc. Sub. Rand.– Woodlawn	S	28	30.74	.61	31.35	877.8	7.90	12:05	12:33	12:20	80	70.22	4.8	150.48
185	Ex. Sub. Rand. – So. Chicago	S	35	75.29	4.98	80.27	2,809.4	12.91	12:20	12:55	12:30	70	196.66	4.2	337.13
	Golf Sp. Rand.- Flossmoor	S	45	......	......	59.25	2,666.4	24.92	12:25	1:10	12:35	40	106.66	2.4	142.20
193	Loc. Sub. Rand. – Woodlawn	S	28	30.74	.61	31.35	877.8	7.90	12:25	12:53	12:41	80	70.22	4.8	150.48
	Equipt. 12th – Burnside	S	40	......	......	167.82	6,712.9	10.53	12:34	1:14	12:44	40	268.52	2.4	402.77
197	Ex. Sub. Rand.– Bl. Is.	S	53	73.26	3.22	76.48	4,053.4	18.94	12:40	1:33	12:50	70	283.74	4.2	321.22
199	Loc. Sub. Rand.– Woodlawn	S	28	30.74	.61	31.35	877.8	7.90	12:45	1:13	1:01	80	70.22	4.8	150.48
203	Add. Pass. Rand. – I. C.	S	30	......	......	73.00	2,190.1	12.50	12:50	1:20	......	40	87.60	2.4	175.20
205	Pass. Big 4 12th – Flossmoor	S	45	......	......	171.41	7,713.5	23.47	1:00	1:45	1:08	40	308.54	2.4	411.38
207	Ex. Sub. Rand.– So. Chicago	S	35	75.29	2.66	77.95	2,728.25	12.91	1:00	1:35	......	70	190.98	4.2	327.39
211	Ft. I. C. Rand.– Flossmoor	S	112	......	......	323.63	36,246.1	24.92	1:00	2:52	1:29	20	724.92	1.2	388.36
213	Loc. Sub. Rand.– Woodlawn	S	28	30.74	.61	31.35	877.8	7.90	1:05	1:33	1:20	80	70.22	4.8	150.48
217	Pass. M. C. 12th – Kensington	S	30	......	......	102.89	3,086.6	13.09	1:15	1:45	1:22	40	123.47	2.4	246.94
219	Ex. Sub. Rand.– Harvey	S	49	81.84	5.37	87.21	4,273.3	20.07	1:20	2:09	1:28	70	299.13	4.2	366.28
	Eng. 12th – Burnside	S	40	......	......	24.88	995.1	10.53	1:23	2:03	1:33	30	29.85	1.8	44.78
221	Loc. Sub. Rand.– Woodlawn	S	28	30.74	1.22	31.96	894.9	7.90	1:25	1:53	.....	80	71.59	4.8	153.41
223	Pass. W. C. 12th – I. C.	S	25	......	......	118.10	2,952.4	11.00	1:30	1:55	.....	40	118.10	2.4	183.44
225	Ex. Sub. Rand.– So. Chicago	S	35	75.29	5.98	81.27	2,844.4	12.91	1:40	2:15	1:50	70	199.11	4.2	341.33
229	Loc. Sub. Rand.– Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	1:45	2:13	2:01	80	69.78	4.8	149.52
	Equipt. 12th – Burnside	S	40	......	......	130.57	5,222.9	10.53	1:56	2:36	2:06	40	208.92	2.4	313.37
231	Ex. Sub. Rand. – Bl. Is.	S	53	73.26	3.86	77.12	4,087.4	18.94	2:00	2 53	2:10	70	286.12	4.2	323.90
233	Pass. Freeport Div. 12th I. C.	S	25	......	......	119.37	2,984.3	11.00	2:00	2:25	.....	40	119.37	2.4	286.49
237	Loc. Sub. Rand.– Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	2:05	2:33	2:20	80	69.78	4.8	149.52
241	Ex. Sub. Rand.– So. Chicago	S	35	75.29	5.31	80.60	2,821.0	12.91	2:20	2:55	2:30	70	197.47	4.2	338.52
243	Loc. Sub. Rand.– Woodlawn	S		30.74	.41	31.15	872.2	7.90	2:25	2:53	2:42	80	69.78	4.8	149.52

	Pass. I. C.	12th – Flossmoor	S	45	... ..	... ..	190.89	8,590.0	23.47	2:30– 3:15	2:36	40	343.60	2.4	458.14
247	Ex. Sub.	Rand.– Flossmoor	S	57	89.54	7.84	97.38	5,550.7	24.92	2:40– 3:37	2:48	70	388.55	4.2	409.10
249	Loc. Sub.	Rand. – Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	2:45– 3:13	3:01	80	69.78	4.8	149.52
251	Pass. M. C.	12th – Kensington	S	35	... ..	... ..	192.99	5,754.4	13.09	3:00– 3:35	3:23	40	270.18	2.4	463.08
253	Ex. Sub.	Rand.– So. Chicago	S	35	91.76	7.47	99.23	3,473.0	12.91	3:00– 3:35	3:10	70	243.11	4.2	406.77
257	Ft. I. C.	Fordham – Floss.	S	55	... ..	.....	268.45	14,764.8	13.49	3:00– 3:55	......	20	295.30	1.2	322.14
259	Loc. Sub.	Rand.— Woodlawn	S	28	30.74	.61	31.35	877.8	7.90	3:05– 3:33	3:21	80	70.22	4.8	150.48
261	Ex. Sub.	Rand.– Bl. Is.	S	53	73.26	5.80	79.06	4,190.2	18.94	3:20– 4:13	3:30	70	293.31	4.2	332.05
265	Loc. Sub.	Rand.– Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	3:25– 3:53	3:41	80	69.78	4.8	149.52
267	Pass. Freeport Div.	12th–I. C.	S	25	... ..	... ..	156.33	3,908.3	11.00	3:30– 3:55	......	40	156.33	2.4	375.19
271	Ex. Sub.	Rand.– So. Chicago	S	35	75.29	5.98	81.27	2,844.5	12.91	3:40– 4:15	3:50	70	199.12	4.2	341.33
273	Pass. I. C.	12th – Flossmoor	S	54	... ..	... ..	172.66	9,323.9	23.47	3:45– 4:39	3:54	40	372.96	2.4	414.38
275	Loc. Sub.	Rand.– Woodlawn	S	28	30.74	.41	31.15	872.2	7.90	3:45– 4:13	4:00	80	69.78	4.8	150.48
277	Ex. Sub.	Rand.– Floss.	S	60	101.68	4.51	106.19	6,371.4	24.92	3:50– 4:50	3:58	70	446.00	4.2	446.00
279	Pass. W. C.	12th – I. C.	S	25	... ..	... ..	118.10	2,952.4	11.00	4:00– 4:25	......	40	118.10	2.4	283.44
281	Ex. Sub.	Rand.– Bl. Is.	S	60	79.36	3.58	82.94	4,976.4	18.94	4:00– 5:00	4:10	70	348.35	4.2	348.35
285	Loc. Sub.	Rand.– Woodlawn	S	28	59.01	1.04	60.05	1,681.4	7.90	4:05– 4:33	4:19	80	134.51	4.8	288.24
289	Ex. Sub.	Rand.– So. Chicago	S	35	111.37	7.97	119.34	4,176.9	12.91	4:20– 4:55	4:29	70	292.38	4.2	501.23
291	Loc. Sub.	Rand.– Woodlawn	S	28	30.74	1.22	31.96	924.9	7.90	4:25– 4:53	4:41	80	74.79	4.8	153.41
	Eng.	Rand.– Burnside	S	45	......	... ..	25.16	1,132.2	11.98	4:29– 5:14	4:44	30	33.97	1.8	45.29
293	Ex. Sub.	Rand.– Kensington	S	37	79.97	5.64	85.61	3,167.6	14.54	4:30– 5:07	4:40	70	221.73	4.2	359.56
297	Ex. Sub.	Rand.– 12th	S	60	65.06	5.72	70.78	4,246.8	18.94	4:40– 5:40	4:52	70	297.38	4.2	297.38
299	Loc. Sub.	Rand.– Woodlawn	S	28	30.74	1.62	72.36	2,026.1	7.90	4:45– 5:13	5:00	80	162.09	4.8	347.33
301	Ex. Sub.	Rand.– So. Chicago	S	35	91.76	6.64	98.40	3,444.0	12.91	4:50– 5:25	5:02	70	241.08	4.2	413.28
303	Pass M. C.	12th – Kensington	S	30	... ..	... ..	122.30	3,669.1	13.09	4:55– 5:25	5:03	40	146.76	2.4	293.52
305	Loc. Sub.	Rand.– 67th	S	30	29.68	1.96	31.64	949.2	8.40	4:55– 5:25	5:13	80	75.94	4.8	151.87
307	Pass. M. C.	12th – Kensington	S	30	... ..	....	199.88	5,996.5	13.09	5:00– 5:30	5:08	40	239.86	2.4	479.71
309	Ex. Sub.	Rand.– Harvey	S	63	79.01	6.42	85.43	5,382.0	20.07	5:00– 6:03	5:09	70	323.24	4.2	358.81
313	Ex. Sub.	Rand.– 67th	S	20	43.68	2.35	46.03	920.6	8.40	5:05– 5:25	5:14	70	64.44	4.2	193.33
315	Loc. Sub.	Rand.– Woodlawn	S	28	88.51	7.80	96.31	2,696.7	7.90	5:05– 5:33	5:23	80	215.74	4.8	462.29
317	Ex. Sub.	Rand.– So. Chicago	S	35	111.37	9.96	121.33	4,246.6	12.91	5:10– 5:45	5:19	70	297.26	4.2	509.59
319	Bus. Men's Spec.	Rand.–Floss.	S	45	82.77	7.38	90.15	4,056.8	24.92	5:10– 5:55	5:19	40	162.37	2.4	216.36
321	Ex. Sub.	Rand.– Bl. Is.	S	55	84.32	7.40	91.72	5,044.6	18.94	5:15– 6:10	5:24	70	353.12	4.2	385.22
323	Ft. M. C.	Rand.– Kensington	S	60	... ..	... ..	301.58	18,095.0	14.54	5:15– 6:15	7:39	20	361.90	1.2	361.90
325	Loc. Sub.	Rand.– Burnside	S	43	85.47	6.00	91.47	3,933.2	11.98	5:15– 5:58	5:32	60	235.99	3.6	329.29
327	Ex. Sub.	Rand.– So. Chicago	S	35	91.76	7.47	99.23	3,473.0	12.91	5:20– 5:55	5:29	70	243.11	4.2	416.77
329	Pass. I. C.	12th – Floss.	S	45	... ..	... ..	163.40	7,353.1	23.47	5:20– 6:05	5:27	40	294.12	2.4	392.16
333	Ex. Sub.	Rand.– 67th	S	20	43.68	5.87	49.55	991.0	8.40	5:25– 5:45	5:35	70	69.37	4.2	208.11
335	Loc. Sub.	Rand.– Woodlawn	S	28	71.92	5.85	77.77	2,177.6	7.90	5:25– 5:53	5:41	80	174.21	4.8	373.30
337	Ex. Sub.	Rand.– Floss.	S	60	123.41	11.04	134.45	8,067.0	24.92	5:30– 6:30	5:38	70	564.69	4.2	564.69

Train No.	Train Classification		Direction of Run	Total Time of Run in Minutes	Ton Miles per Minute			Totall Ton Miles	Miles Run	Time		Observed Time at 39th St.	Estimated Watt-Hrs. per Ton Mile	Total Kilowatt-Hrs. on Run	Kilowatts per Ton Mile per Minute	Instantaneous Kilowatts
					Train C_1	Load C_2P	Total $C_1 + C_2P$			Leave	Arrive					
339	Loc. Sub.	Rand.– Burnside	S	45	28.62	2.65	31.27	1,407.1	11.98	5:30–	6:15	5:46	60	84.43	3.6	112.57
343	Ex. Sub.	Rand.– So. Chicago	S	35	111.37	10.96	122.33	4,281.6	12.91	5:35–	6:10	5:43	70	299.71	4.2	513.79
345	Loc. Sub.	Rand. Gr. Cross.	S	36	64.48	4.06	68.54	2,467.4	9.48	5:35–	6:11	5:51	60	148.04	3.6	246.74
347	Ft. I. C.	Rand.– Floss.	S	88	... ..	.....	372.24	32,757.3	24.92	5:35–	7:03	5:38	20	655.15	1.2	446.69
349	Ex. Sub.	Rand.– Bl. Is.	S	55	102.34	10.22	112.56	6,190.8	18.94	5:39–	6:34	5:48	70	433.36	4.2	472.75
351	Loc. Sub.	Rand.– Burnside	S	45	66.96	1.81	68.77	3,094.7	11.98	5:40–	6:25	5:56	60	185.68	3.6	247.57
353	Ex. Sub.	Rand.– So. Chicago	S	35	91.76	8.30	100.06	3,502.1	12.91	5:34–	6:18	5:52	70	245.15	4.2	420.25
355	Loc. Sub.	Rand.– Burnside	S	45	54.94	2.90	57.84	2,602.8	11.98	5:45–	6:30	5:59	60	156.17	3.6	208.22
361	Ex. Sub.	Rand. Homewood	S	58	123.41	12.14	135.55	7,861.9	23.54	5:47–	6:45	5:55	70	550.33	4.2	569.31
363	Pass. Freeport Div.	12th. I. C.	S	25	... ..	... ..	264.22	6,605.5	11.00	5:50–	6:15	......	40	264.22	3.4	634.13
365	Ex. Sub.	Rand.– So. Chicago	S	35	111.37	9.96	121.33	7,861.9	12.91	5:51–	6:26	6:00	70	550.33	4.2	509.59
367	Loc. Sub.	Rand.– Burnside	S	44	40.63	2.90	43.53	1,915.3	11.98	5:51–	6:35	6:07	60	114.92	3.6	156.71
369	Ex. Sub.	Rand.– Burnside	S	33	73.26	7.08	80.34	2,651.2	11.98	5:55–	6:28	6:03	70	185.58	4.2	337.33
371	Loc. Sub.	Rand.– Burnside	S	45	54.94	3.38	58.32	2,624.4	11.98	5:55–	6:40	6:11	60	157.46	3.6	209.95
373	Ex. Sub.	Rand.– Bl. Is.	S	56	102.34	8.52	110.86	6,208.2	18.94	5:59–	6:55	6:09	70	434.57	4.2	465.61
375	Pass. Freeport Div.	12th.– I. C.	S	25	... ..	... ..	271.04	6,776.0	11.00	6:00–	6:25	......	40	271.04	2.4	650.50
377	Pass. I. C.	12th– Floss.	S	53	... ..	... ..	266.98	14,150.1	23.47	6:00–	6:53	6:17	40	566.00	2.4	640.75
379	Loc. Sub.	Rand.– Burnside	S	45	54.94	1.45	56.39	2,537.6	11.98	6:00–	6:45	6:17	60	152.86	3.6	202.00
385	Ex. Sub.	Rand.– Burnside	S	35	69.19	6.51	75.70	2,649.5	11.98	6:03–	6:38	6:14	70	185.46	4.2	317.94
387	Loc. Sub.	Rand.– Burnside	S	45	28.62	.95	29.57	1,330.65	11.98	6:05–	6:50	6:21	60	79.84	3.6	106.45
	Eng.	Rand.– Burnside	S	45	... ..	... ..	25.16	1,132.1	11.98	6:06–	6:51	6:21	30	33.96	1.8	45.29
389	Ft. Freeport Div.	Rand. – I. C.	S	35	.....	... ..	301.61	10,556.3	12.50	6:10–	6:45	......	20	211.13	1.2	361.93
391	Ex. Sub.	Rand.– So. Chicago	S	35	111.37	9.96	121.33	4,246.6	12.91	6:10–	6:45	6:20	70	297.26	4.2	509.59
393	Loc. Sub.	Rand.– Burnside	S	45	54.94	.97	55.91	2,516.0	11.98	6:10–	6:55	6:27	60	150.96	3.6	201.28
395	Add. Pass.	Rand.– I. C.	S	30	... ..	.....	73.00	2,190.1	12.50	6:12–	6:42	......	40	87.60	2.4	175.20
397	Ex. Sub.	Rand.– Burnside	S	33	73.26	5.12	78.38	2,586.5	11.98	6:15–	6:48	6:24	70	171.06	4.2	329.20
399	Loc. Sub.	Rand.– Burnside	S	45	28.62	.76	29.38	1,322.1	11.98	6:15–	7:00	6:30	60	79.33	3.6	105.77
409	Ex. Sub.	Rand.– Floss.	S	54	96.57	8.72	105.29	6,738.4	24.92	6:20–	7:24	6:28	70	471.69	4.2	442.22
411	Ft. Freeport Div.	Rand.– I. C.	S	35	... ..	... ..	301.61	10,556.3	12.50	6:20–	6:55	......	20	211.13	1.2	361.93
413	Loc. Sub.	Rand.– Burnside	S	43	29.68	1.96	31.64	1,360.52	11.98	6:25–	7:08	6:41	60	81.63	3.6	113.90
415	Pass. W. C.	12th – I. C.	S	25	... ..	... ..	225.81	5,645.2	11.00	6:30–	6:55	....	40	225.81	2.4	541.94

417	Ex. Sub.	Rand.– So. Chicago	S	35	91.76	9.13	100.89	3,531.2	12.91	6:30– 7:05	6:40	70	277.18	4.2	423.74
421	Ft. I. C.	Rand.– Floss.	S	85	... ..	... ..	256.38	21,792.5	24.92	6:30– 7:55	8:21	20	435.85	1.2	307.66
423	Ft. W. C.	Rand.– I. C.	S	35	... ..	.....	301.61	10,556.3	12.50	6:30– 7:05	....	20	211.13	1.2	361.93
425	Loc. Sub.	Rand.– Burnside	S	45	54.94	.97	55.91	2,516.0	11.98	6:35– 7:20	6:50	60	150.96	3.6	201.28
427	Ft. M. C.	Rand.– Kens.	S	45	... ..	.....	444.11	19,985.2	14.54	6:35– 7:20	8:03	20	399.70	1.2	532.93
429	Ex. Sub.	Rand.– Bl. Is.	S	57	95.70	6.70	102.40	5,836.6	18.94	6:40– 7:37	6:48	70	408.56	4.2	430.08
431	Ft. I. C.	Rand.– Floss.	S	90	... ..	... ..	307.48	27,673.3	24.92	6:40– 8:10	8:52	20	553.47	1.2	368.48
433	Loc. Sub.	Rand.– S. Chicago	S	45	30.74	2.03	32.77	1,475.6	12.91	6:45– 7:30	7:01	60	88.54	3.6	117.97
435	Ft. W. C.	Rand.– I. C.	S	35	... ..	... ..	301.61	10,556.3	12.50	6:45– 7:10	......	20	211.13	1.2	361.93
437	Ft. I. C.	Rand.– Floss.	S	93	... ..	.....	249.06	23,163.1	24.92	6:45– 8:18	9:20	20	463.26	1.2	298.87
	Eng.	12th – Burnside	S	40	... ..	.....	24.88	995.1	10.53	6:57– 7:37	7:07	30	29.85	1.8	44.78
439	Loc. Sub.	Rand.– Floss.	S	73	69.19	4.86	74.05	5,405.6	24.92	7:00– 8:13	7:16	60	324.34	3.6	266.58
441	Ft. Freeport Div.	Rand.– I. C.	S	35	... ..	... ..	301.61	10,556.3	12.50	7:05– 7:40	......	20	211.13	1.2	361.93
443	Loc. Sub.	Rand. S. Chicago	S	45	59.01	4.68	63.69	2,866.1	12.91	7:30– 8:15	7:47	60	171.97	3.6	229.28
445	Ft. W. C.	Rand.– I.C.	S	35	... ..	.....	301.61	10,556.3	12.50	7:30– 8:05	......	20	211.13	1.2	361.93
447	Loc. Sub.	Rand.– Bl. Is.	S	35	59.01	4.68	63.69	4,139.9	18.94	8:00– 9:05	8:15	60	248.39	3.6	229.28
449	Loc. Sub.	Rand.– So. Chicago	S	45	59.01	4.16	63.17	2,842.7	12.91	8:30– 9:15	8:46	60	170.56	3.6	227.41
	Ft. C. C. L.	Rand.– Riverdale	S	30	... ..	...	183.93	14,714.5	17.22	8:37– 9:57	8:57	20	294.29	1.2	220.72
451	Pass. Big 4	12th – Floss.	S	55	... ..	.....	198.26	10,904.2	23.47	9:00– 9:55	9:09	40	436.17	2.4	475.82
453	Loc. Sub.	Rand.– Floss.	S	45	67.49	4.42	71.91	5,197.6	24.92	9:00–10:12	9:19	60	311.86	3.6	258.88
457	Pass. I. C.	12th – Floss.	S	64	... ..	.....	164.57	9,545.2	23.47	9:05–10:03	9:14	40	381.81	2.4	394.97
459	Ft. I. C.	Rand.– Floss.	S	85	... ..	.....	290.13	24,661.5	24.92	9:15–10:40	12:23	20	493.23	1.2	348.16
461	Pass. C. C. L.	12th – Riverdale	S	40	... ..	... ..	119.77	4,789.9	14.55	9:30–10:10	9:38	40	191.60	2.4	287.45
463	Loc. Sub.	Rand.– So. Chicago	S	45	59.01	4.16	63.17	2,842.7	12.91	9:30–10:15	9:46	60	162.56	3.6	227.41
465	Pass. M. C.	12th – Kens.	S	32	... ..	.....	212.88	6,812.0	13.09	9:35–10:07	9:44	40	272.38	2.4	510.91
467	Pass. M. C.	12th – Kens.	S	35	... ..	.....	182.99	6,204.7	13.09	10:00–10:35	10:10	40	248.19	2.4	439.18
469	Loc. Sub.	Rand.– Bl. Is.	S	65	59.01	4.16	63.17	4,106.1	18.94	10:00–11:05	10:17	60	246.37	3.6	227.41
	Ft. M. C.	Rand.– Kens.	S	65	... ..	... ..	245.97	15,986.7	14.54	10:11–11:16	10:31	20	319.73	1.2	295.12
471	Pass. I. C.	12th – Floss.	S	50	... ..	.....	242.21	12,110.5	23.47	10:15–11:05	10:25	40	484.42	2.4	581.30
473	Ft. I. C.	Ford.– Floss.	S	33	... ..	... ..	328.11	14,764.8	13.49	10:20–10:53	......	20	295.39	1.2	393.73
475	Pass. W. C.	12th – I. C.	S	35	... ..	... ..	301.61	10,556.3	11.00	10:30–11:05	......	40	422.25	2.4	361.93
477	Loc. Sub.	Rand.– So. Chicago	S	45	59.01	4.16	63.17	2,842.7	12.91	10:30–11:15	10:45	60	170.56	3.6	227.41
479	Loc. Sub.	Rand.– Kens.	S	45	65.06	2.86	67.92	3,056.4	14.54	10:50–11:35	11:05	60	183.38	3.6	244.51
	Eng.	Rand.– Burnside	S	45	... ..	... ..	25.16	1,132.1	11.98	10:51–11:36	11:06	30	33.96	1.8	45.29
481	Ft. I. C.	Ford.– Floss.	S	45	... ..	.....	328.11	14,764.8	13.49	10:00–11:45	....	20	295.30	1.2	393.73
485	Ex. Sub.	Rand.– So. Chicago	S	35	111.37	7.96	119.33	4,176.6	12.91	11:10–11:45	11:20	70	292.36	4.2	501.19
487	Loc. Sub.	Rand.– Woodlawn	S	35	61.62	3.54	65.16	1,629.0	7.90	11:10–11:35	11:27	80	130.32	4.8	312.77
491	Ex. Sub.	Rand.– Floss.	S	57	132.44	10.00	142.44	8,119.1	24.92	11:25–12:22	11:34	70	568.34	4.2	598.25
493	Loc. Sub.	Rand.– So. Chicago	S	45	88.51	2.34	90.85	4,888.3	12.91	11:25–12:10	11:45	60	245.30	3.6	327.06
495	Pass. Big 4	12th – Floss.	S	45	... ..	... ..	176.70	7,946.9	23.47	11:30–12:15	11:38	40	317.88	2.4	424.08

Train No.	Train Classification		Direction of Run	Total Time of Run in Minutes	Ton Miles per Minute			Total Ton Miles	Miles Run	Time	Observed Time at 39th St.	Estimated Watt-Hrs. per Ton Mile	Total Kilowatt-Hrs. on Run	Kilowatts per Ton Mile per Minute	Instantaneous Kilowatts
					Train C_1	Load C_2P	Total $C_1 + C_2P$			Leave Arrive					
	Ft. M. C.	Rand.– Kens.	S	65	......	......	273.91	17,804.2	14.54	11:30–12:35	11:50	20	356.08	1.2	328.69
	Eng.	12th – Burnside	S	40	......	......	24.88	995.1	10.53	11:35–12:15	11:45	30	29.85	1.8	44.78
499	Ex. Sub.	Rand.– Bl. Is.	S	53	89.28	6.41	95.72	5,073.2	18.94	11:40–12:33	11:50	70	355.12	4.2	402.02
501	Loc. Sub.	Rand.– So. Chicago	S	45	59.01	2.60	61.61	2,772.5	12.91	11:50–12:35	12:03	60	166.35	3.6	221.80
2	Loc. Sub.	So. Chicago.– Rand.	N	45	59.01	1.56	60.57	2,725.6	12.91	11:30–12:15	12:03	60	163.54	3.6	218.05
4	Loc. Sub.	Kens. – Rand.	N	45	65.06	.29	65.35	2,940.8	14.54	11:45–12:30	12.18	60	176.45	3.6	235.26
	Ft. M. C.	Kens.– Rand.	N	65	182.20	.00	182.20	11,843.0	14.54	11:31–12:36	12:16	20	236.86	1.2	218.64
6	Loc. Sub.	So. Chicago.– Rand.	N	45	87.29	1.17	88.46	3,980.7	12.91	12:05–12:50	12:35	60	238.84	3.6	318.46
	Ft. I. C.	Floss.– Rand.	N	105	......	......	322.65	33,878.6	24.92	12:43– 2:28	2:08	20	677.57	1.2	397.18
	Pass. I. C. M. C.	Burnside– 12th	N	40	......	......	170.72	6,828.7	10.53	12:18– 2:58	2:38	40	273.15	2.4	409.73
8	Ft. I. C.	Floss.– Fordham	N	75	......	......	219.35	16,451.1	13.49	1:45– 3:00	......	20	329.02	1.2	263.22
	Pass. I. C.	Mt. Burns – Rand.	N	45	......	......	28.22	1,269.9	11.98	2:56– 3:41	3:16	40	50.80	2.4	67.73
10	Ft. Freeport Div. I. C.–	Rand.	N	35	......	......	301.61	10,556.3	12.50	3:10– 3:45	......	20	211.13	1.2	361.93
12	Ft. I. C.	Floss.–Rand.	N	105	......	......	214.67	22,540.1	24.96	2:30– 4:15	3:45	20	450.80	1.2	257.57
	Ft. I. C.	Burnside– Rand.	N	40	......	......	77.42	3,096.2	11.98	3:12– 3:52	3:37	30	92.89	1.8	139.34
14	Ft. I. C.	Burnside– Rand.	N	100	......	......	31.09	3,108.8	11.98	2:50– 4:30	4:06	30	93.26	1.8	55.96
16	Ft. Freeport Div. I. C.–	Rand.	N	35	......	......	301.61	10,556.3	12.50	3:55– 4:30	......	20	211.13	1.2	361.93
	Ft.C.C.&.L	Riverdale – Rand.	N	80	......	......	151.64	12,131.5	17.22	3:16– 4:36	4:16	20	242.63	1.2	181.97
18	Ft. I. C.	Floss.– Rand.	N	110	......	......	109.76	12,073.6	24.92	3:00– 4:50	5:21	20	241.47	1.2	131.71
	Ft. M. C.	Kens.–Rand.	N	65	......	......	358.91	23,329.4	14.54	3:53– 4:58	4:38	20	466.59	1.2	430.69
26	Ft. I. C.	Floss.– Rand.	N	103	......	......	182.54	18,802.4	24.92	3:42– 5:25	5:36	20	376.05	1.2	219.05
28	Ft. W. C.	City Limits – Rand.	N	35	......	......	301.61	10,556.3	12.50	4:55– 5:30	......	20	211.13	1.2	361.93
30	Loc. Sub.	Homewood – Rand.	N	75	93.31	.86	194.17	7,062.6	23.54	4:30– 5:45	5:31	60	423.76	3.6	699.01
	Ft. I. C.	Floss.– Rand.	N	105	......	......	291.80	30,639.1	24.92	4:15– 6:00	5:40	20	612.78	1.2	340.16
32	Ft. M. C.	Kens.– Rand.	N	65	......	......	269.44	17,513.4	14.54	5:00– 6:05	5:48	20	350.27	1.2	323.33
	Ft. I. C.	Floss.– Rand.	N	105	......	......	187.37	19,674.3	24.92	4:24– 6:09	5:49	20	393.49	1.2	224.84
	Ft. I. C.	Floss.– Rand.	N	105	......	......	190.93	20,048.1	24.92	4:29– 6:14	5:54	20	400.96	1.2	229.12
34	Loc. Sub.	So. Chicago.– Rand.	N	45	59.01	1.30	60.31	2,713.9	12.91	5:40– 6:25	6:11	60	162.83	3.6	217.12
36	Pass. I. C.	Floss. – 12th.	N	52	......	......	227.80	11,845.40	23.47	5:38– 6:30	6:20	40	473.82	2.4	546.72

38	Loc. Sub.	Bl. Is.– Rand.	N	65	71.92	5.53	77.45	5,034.3	18.94	5:40– 6:45	6:32	60	302.06	3.6	278.82
40	Ft. I. C.	Floss.– Rand.	N	100	.... ..	.....	507.00	50,699.7	24.92	5:10– 6:50	8:45	20	1013.99	1.2	608.40
42	Pass.C.C. &. L.	Riverdale–12th	N	40	.... ..	.....	113.23	4,529.1	15.77	6:10– 6:50	6:47	40	181.16	2.4	271.75
44	Ft. Freeport Div.	I. C.– Rand.	N	35	.... ..	.....	301.61	10,556.3	12.50	6:25– 7:00	......	20	211.13	1.2	361.93
46	Loc. Sub.	Burnside– Rand.	N	50	59.52	2.43	61.95	3,097.5	11.98	6:10– 7:00	6:46	60	185.85	3.6	223.02
60	Loc. Sub.	Bl. Is.– Kens.	N	17	.... ..	.....	50.99	866.8	4.40	6:43– 7:00	......	60	52.01	3.6	183.56
50	Ex. Sub.	So. Chicago. –Rand.	N	35	75.29	6.64	81.93	2,867.55	12.91	6:35– 7:10	7:02	70	200.73	4.2	344.11
54	Pass. Big 4	Floss. – 12th	N	52	.... ..	.....	213.67	11,110.7	23.47	6:18– 7:10	7:01	40	444.43	2.4	512.81
52	Loc. Sub.	Homewood – Rand.	N	70	69.19	1.82	71.01	4,970.7	23.54	6:05– 7:15	7:01	60	298.24	3.6	255.64
	Eng.Tr.No.40	to 26th St.House	N	9	.... ..	.....	21.00	189.0	2.00	7:06– 7:15	7:06	30	5.67	1.8	37.80
56	Pass. M. C.	Kens.– 12th.	N	32	.... ..	.....	138.67	4,437.51	13.09	6:43– 7:15	7:05	40	177.50	2.4	332.81
58	Ex. Sub.	Bl. Is.– Rand.	N	58	67.15	5.92	73.07	4,238.1	18.94	6:22– 7:20	7:11	70	296.67	4.2	306.89
62	Loc. Sub.	Burnside– Rand.	N	50	25.44	.84	26.28	1,311.5	11.98	6:35– 7:25	7:11	60	78.69	3.6	94.61
66	Pass. I C.	Floss.– 12th	N	57	.... ..	.....	195.17	11,124.8	23.47	6:30– 7:27	7:18	40	444.99	2.4	468.41
68	Ex. Sub.	So. Chicago – 12th	N	35	91.76	7.05	98.81	3,458.4	12.91	6:55– 7:30	7:22	70	242.09	4.2	415.00
70	Pass. M. C.	Kens.– 12th	N	35	.... ..	.....	260.41	9,114.6	13.09	6:55– 7:30	7:23	40	364.58	2.4	624.98
74	Ex. Sub.	Homewood – Rand.	N	58	83.43	6.27	89.70	5,202.6	23.54	6:37– 7:35	7:27	70	364.18	4.2	376.74
76	Loc. Sub.	Burnside– 12th	N	48	26.50	2.10	27.60	1,324.8	11.98	6:47– 7:35	7:21	60	79.49	3.6	99.36
78	Ex. Sub.	So. Chicago– Rand.	N	35	91.76	8.30	100.06	3,502.1	12.91	7:05– 7:40	7:32	70	245.15	4.2	420.25
80	Loc. Sub.	Burnside– Rand.	N	48	50.88	1.12	52.00	2,496.0	11.98	6:52– 7:40	7:26	60	149.76	3.6	187.20
	Ft. C. C. & L.	Riverside– Rand.	N	80	.... ..	.....	140.88	11,270.5	17.22	6:25– 7:45	7:25	20	225.41	1.2	169.06
84	Loc. Sub.	Burnside– Rand.	N	50	59.52	3.51	63.03	3,151.5	11.98	6:55– 7:45	7:31	60	189.09	3.6	226.91
82	Ex. Sub.	Harvey – Rand.	N	51	117.40	13.35	130.75	6,668.3	20.07	6:54– 7:45	7:37	70	466.78	4.2	549.15
86	Pass. Big 4	Floss.– 12th	N	50	.....	....	158.94	7,946.8	23.47	6:55– 7:45	7:34	40	317.87	2.4	381.46
88	Loc. Sub.	Burnside– Rand.	N	46	52.91	3.25	56.16	2,583.4	11.98	7:04– 7:50	7:35	60	155.00	3.6	202.18
90	Ex. Sub.	So. Chicago– Rand.	N	35	111.37	10.96	112.33	3,931.6	12.92	7:15– 7:50	7:43	70	275.21	4.2	471.79
92	Loc. Sub.	Burnside– Rand.	N	45	40.63	7.09	47.62	2,142.9	11.98	7:10– 7:55	7:41	60	128.57	3.6	171.43
94	Ex. Sub.	Floss.– Rand.	N	57	132.44	13.52	145.96	8,319.7	24.92	6:58– 7:55	7:46	70	582.38	4.2	613.03
98	Loc. Sub.	Burnside– Rand.	N	44	54.94	4.11	59.05	2,598.2	11.98	7:16– 8:00	7:46	60	155.89	3.6	212.58
102	Ex. Sub.	Burnside– Rand.	N	34	71.23	6.08	77.31	2,628.5	11.98	7:26– 8:00	......	70	184.20	4.2	324.70
104	Loc. Sub.	Burnside– Rand.	N	46	52.91	3.71	56.62	2,623.5	11.98	7:19– 8:05	7:50	60	157.41	3.6	203.83
106	Ex. Sub.	Bl. Is. I. C.– Rand.	N	50	114.38	11.15	125.53	6,276.5	18.94	7:15– 8:05	7:54	70	439.36	4.2	527.23
108	Loc. Sub.	Woodlawn – Rand.	N	28	59.01	4.68	63.69	1,652.3	7.90	7:42– 8:10	7:55	80	132.18	4.8	305.71
110	Ex. Sub.	So. Chicago– Rand.	N	35	111.37	13.84	125.21	4,382.4	12.91	7:35– 8:10	8:02	70	306.77	4.2	525.88
	Ft. M. C.	Kens.– Rand.	N	65	.... ..	.....	298.67	19,403.6	14.54	7:10– 8:15	7:55	20	388.07	1.2	358.40
112	Loc. Sub.	Burnside– Rand.	N	47	26.50	2.62	29.12	1,368.6	11.98	7:28– 8:15	8:00	60	82.12	3.6	104.83
114	Ex. Sub.	Burnside– Rand.	N	35	84.32	7.60	91.92	3,217.2	11.98	7:40– 8:15	8:06	70	225.20	4.2	386.06
116	Loc. Sub.	Burnside – Rand.	N	44	54.94	3.87	58.81	2,587.6	11.98	7:36– 8:20	......	60	155.26	3.6	211.72
118	Ex. Sub.	Burnside – Rand.	N	33	89.28	12.07	101.35	3,344.6	11.98	7:47– 8:20	8:11	70	244.12	4.2	425.67
122	Loc. Sub.	Burnside – Rand.	N	47	26.50	3.15	27.65	1,299.6	11.98	7:38– 8:25	8:10	60	77.98	3.6	99.54

Train No.	Train Classification	Direction of Run	Total Time of Run in Minutes	Ton Miles per Minute: Train C_1	Ton Miles per Minute: Load C_2P	Ton Miles per Minute: Total $C_1 + C_2P$	Total Ton Miles	Miles Run	Time: Leave	Time: Arrive	Observed Time at 39th St.	Estimated Watt-Hrs. per Ton Mile	Total Kilowatt-Hrs. on Run	Kilowatts per Ton Mile per Minute	Instantaneous Kilowatts
124	Ex. Sub. Floss.– Rand.	N	65	117.40	14.42	131.82	8,568.3	24.92	7:20–	8:25	8:18	70	599.78	4.2	553.64
126	Add. Pass. – Rand.	N	30	...	...	73.00	2,190.1	12.50	7:58–	8:28	......	40	87.60	2.4	175.20
128	Loc. Sub. Woodlawn – Rand.	N	28	59.01	3.12	62.13	1,739.7	7.90	8:02–	8:30	8:16	80	139.18	4.8	298.22
132	Ex. Sub. So. Chicago – Rand.	N	35	91.76	9.13	100.89	3,531.2	12.91	7:55–	8:30	8:21	70	247.18	4.2	423.74
134	Freeport Div. I. C.– 12th	N	25	...	...	224.80	5,619.9	11.00	8:05–	8:30	......	40	224.80	2.4	539.52
136	Pass. W. C. – 12th	N	25	...	...	140.71	3,517.8	11.00	8:05–	8:30	......	40	140.61	2.4	337.70
138	Bus. Men's Spec. Floss.– Rand.	N	45	82.79	6.64	89.43	4,024.35	24.92	7:48–	8:33	8:22	70	281.70	4.2	375.61
140	Ex. Sub. Gr. Cross.– Rand.	N	24	99.20	7.60	106.80	2,563.2	9.48	8:11–	8:35	8:26	70	179.42	4.2	448.56
142	Loc. Sub. Burnside – Rand.	N	46	27.56	2.18	29.74	1,368.04	11.98	7:49–	8:35	8:20	60	82.08	3.6	107.06
146	Loc. Sub. Burnside – Rand.	N	43	56.98	1.50	58.48	2,514.64	11.98	7:57–	8:40	8:25	60	150.88	3.6	210.53
148	Ex. Sub. Bl. Is.– Rand.	N	53	109.12	9.80	118.92	6,302.76	18.94	7:47–	8:40	8:30	70	441.19	4.2	499.46
150	Ex. Sub. 67th – Rand.	N	20	85.47	5.64	91.11	1,822.20	8.40	8:25–	8:45	......	70	127.55	4.2	382.66
152	Loc. Sub. Woodlawn – Rand.	N	28	59.01	2.08	61.09	1,710.52	7.90	8:17–	8:45	8:32	80	136.84	4.8	293.23
156	Pass. M. C. Kens.– Rand.	N	35	...	...	195.98	6,859.2	13.09	8:10–	8:45	8:41	40	274.37	2.4	470.35
158	Ex. Sub. So. Chicago – Rand.	N	35	111.37	8.96	120.33	4,211.55	12.91	8:15–	8:50	8:44	70	294.81	4.2	505.39
160	Loc. Sub. Woodlawn – Rand.	N	28	59.01	3.90	62.91	1,761.48	7.90	8:27–	8:55	8:41	80	140.92	4.8	301.97
164	Ex. Sub. Floss.– Rand	N	62	120.40	10.74	131.14	8,130.68	24.92	7:58–	9:00	8:51	70	569.15	4.2	550.79
166	Loc. Sub. Gr. Cross.– Rand.	N	35	54.94	1.69	56.63	1,982.05	9.48	8:30–	9:05	8:50	60	118.92	3.6	203.87
170	Ex. Sub. So. Chicago – Rand.	N	35	91.76	10.37	102.13	3,574.55	12.91	8:35–	9:10	9:00	70	250.22	4.2	428.95
174	Loc. Sub. Woodlawn – Rand.	N	28	30.74	1.21	31.95	864.60	7.90	8:47–	9:15	9:00	80	69.17	4.8	153.36
176	Pass. I. C. Floss.– 12th	N	47	...	...	164.39	7,726.3	23.47	8:28–	9:15	9:06	40	309.04	2.4	394.54
178	Ex. Sub. Bl. Is.– Rand.	N	53	89.28	8.05	97.33	5,158.49	18.94	8:27–	9:20	9:12	70	361.10	4.2	408.79
182	Freeport Div. I. C. Pass.– 12th	N	25	...	...	230.56	5,764.0	11.00	9:05–	9:30	......	40	230.56	2.4	553.35
	Ft. I. C. Floss.– Rand.	N	105	...	...	523.20	54,936.1	24.92	7:49–	9:34	9:14	20	1098.72	1.2	627.84
184	Loc. Sub. Woodlawn– 12th	N	28	30.74	2.43	33.17	928.76	7.90	9:07–	9:35	9:21	80	74.31	4.8	159.22
186	Ex. Sub. So. Chicago.– Rand.	N	35	111.37	8.96	120.33	4,211.55	12.91	9:05–	9:40	9:32	70	294.81	4.2	505.39
188	Pass. W. C. – 12th	N	25	...	...	140.70	3,517.8	11.00	9:05–	9:40	......	40	140.71	2.4	337.68
	Ft. I. C. Floss.– Rand.	N	105	...	...	257.62	27,050.7	24.92	7:56–	9:41	9:21	20	541.01	1.2	309.14
192	Loc. Sub. Woodlawn – Rand.	N	28	30.74	1.02	31.76	889.28	7.90	9:27–	9:55	9:40	80	71.14	4.8	152.45
196	Pass. I. C. Floss. – 12th	N	70	...	...	112.23	785.61	23.47	8:50–	10:00	9:53	40	314.24	2.4	269.35
198	Ex. Sub. Harvey – Rand.	N	50	99.20	7.60	106.80	5,340.00	20.07	9:10–	10:00	9:52	70	373.80	4.2	448.56

200	Freeport Div. I. C. Pass.	– 12th	N	25	......	.....	99.62	2,490.4	11.00	9:45–10:10	......	40	99.62	2.4	239.09
202	Loc. Sub.	Woodlawn – Rand.	N	28	30.74	1.42	32.16	900.48	7.90	9:47–10:15	10:00	80	72.04	4.8	154.37
206	Ex. Sub.	So. Chicago – Rand.	N	35	75.29	6.64	81.93	2,867.55	12.91	9:45–10:20	10:11	70	200.72	4.2	344.11
208	Pass. W. C.	– 12th	N	25	......	.....	99.62	2,490.4	11.00	9:55–10:20	......	40	97.62	2.4	239.09
212	Loc. Sub.	Woodlawn – Rand.	N	28	30.74	1.02	31.76	889.28	7.90	10:07–10:35	10:20	80	71.14	4.8	152.45
218	Ex. Sub.	Bl. Is.– Rand.	N	53	73.26	5.80	78.06	4,137.18	18.94	9:47–10:40	......	70	289.60	4.2	327.85
222	Loc. Sub.	Woodlawn – Rand.	N	28	30.74	1.62	32.36	906.08	7.90	10:27–10:55	10:41	80	72.49	4.8	155.33
226	Ex. Sub.	So. Chicago – Rand.	N	35	75.29	4.98	80.27	2,809.45	12.91	10.25–11:00	10:51	70	196.67	4.2	337.23
	Milk Tr.	Floss.– Rand.	N	75	34.98	9.24	44.22	3,316.50	24.92	9:45–11:00	10:53	60	198.99	3.6	159.19
228	Loc. Sub.	Woodlawn – Rand.	N	28	30.74	2.03	32.77	917.56	7.90	10:47–11:15	11:00	80	73.41	4.8	157.30
232	Ex. Sub.	Floss.– Rand.	N	57	89.54	7.84	97.38	5,550.66	24.92	10:23–11:20	11:11	70	388.55	4.2	409.00
236	Pass. I. C.	Floss.– Rand.	N	47	......	.....	283.39	13,319.2	23.47	10:43–11:30	11:23	40	532.77	2.4	680.14
	Ft. I. C.	Floss.– Rand.	N	105	......	.....	27.17	2,853.3	24.92	9:49–11:34	11:14	30	85.60	1.8	48.91
242	Loc. Sub.	Woodlawn – Rand.	N	28	30.74	2.03	32.77	917.56	7.90	11:07–11:35	......	80	73.41	4.8	157.30
244	Ft. M. C.	Kens.– Rand.	N	60	......	.....	398.52	23,911.0	14.54	10:40–11:40	11:38	20	478.22	1.2	478.22
246	Ex. Sub.	So. Chicago – Rand.	N	35	91.76	6.64	98.40	3,444.0	12.91	11:05–11:40	11:32	70	240.08	4.2	413.28
	Ft. I. C.	Floss.– Rand.	N	105	......	.....	435.39	45,715.74	24.92	10:05–11:50	11:30	20	914.30	1.2	522.47
248	Loc. Sub.	Woodlawn – Rand.	N	28	30.74	1.02	31.76	889.28	7.90	11:27–11:55	11:40	80	71.14	4.8	152.45
252	Ex. Sub.	Bl. Is.– Rand.	N	42	85.47	4.85	90.32	3,793.44	18.94	11:18–12:00	11:51	70	265.54	4.2	379.34
	Ft. I. C.	Floss.– Rand.	N	105	......	.....	319.08	33,503.84	24.92	10:27–12:12	11:52	20	670.08	1.2	382.90
254	Loc. Sub.	Woodlawn – Rand.	N	28	30.74	.81	31.55	883.4	7.90	11:47–12:15	12:00	80	70.67	4.8	151.44
	Ft. M. C.	Kens.– Rand.	N	60	......	.....	265.27	15,914.0	14.54	11:18–12:18	11:58	20	308.32	1.2	318.32
256	Ex. Sub.	So. Chicago – Rand.	N	35	91.76	6.15	97.91	3,426.85	12.91	11:45–12:20	12:11	70	239.88	4.2	411.22
258	Add. Pass.	I. C. – Rand.	N	30	......	.....	73.00	2,190.1	12.50	11:55–12:25	......	40	87.60	2.4	175.20
260	Pass. Freeport Div. I. C.	– 12th	N	25	......	.....	137.85	3,446.3	11.00	12:00–12:25	......	40	137.85	2.4	330.84
266	Loc. Sub.	Woodlawn – Rand.	N	28	30.74	.81	31.55	883.4	7.90	12:07–12:35	......	80	70.67	4.8	151.44
268	Ex. Sub.	Harvey – Rand.	N	50	81.40	7.16	88.56	4,428.00	20.07	11:50–12:40	12:32	70	309.96	4.2	371.95
270	Loc. Sub.	Woodlawn– Rand.	N	28	30.74	.81	31.55	883.4	7.90	12:27–12:55	12:40	80	70.67	4.8	151.44
	Equipt. Pullman	-- 12th	N	40	......	.....	45.25	1,810.6	12.53	12:18–12:58	12:48	40	72.42	2.4	108.60
274	Ex.	So. Chicago– Rand.	N	35	75.29	4.32	79.61	2,786.35	12.91	12:25– 1:00	12:52	70	195.04	4.2	334.36
278	Pass.	W. C.– 12th	N	25	......	.....	118.1	2,952.4	11.00	12:45– 1:05	......	40	118.10	2.4	283.44
280	Loc. Sub.	Woodlawn– Rand.	N	28	30.74	1.22	31.96	894.88	7.90	12:47– 1:15	1:00	80	71.59	4.8	153.41
282	Pass. M. C.	Kens.– 12th	N	34	......	.....	106.95	3,636.4	13.09	12:41– 1:15	1:06	40	145.46	2.4	256.68
284	Ex. Sub.	Bl. Is.– Rand.	N	53	73.26	3.86	77.12	4,087.36	18.94	12:27– 1:20	1:11	70	286.12	4.2	323.90
286	Pass. I. C.	Floss.-- 12th	N	53	......	.....	175.94	9,324.6	23.47	12:27– 1:20	1:21	40	372.98	2.4	422.24
292	Loc. Sub.	Woodlawn– Rand.	N	28	30.74	.81	31.55	883.40	7.90	1:07– 1:35	1:20	80	70.67	4.8	151.44
	Ft. M. C.	Kens.– Rand.	N	65	......	.....	89.80	5,736.0	14.54	12:40– 1:45	1:25	20	114.72	1.2	107.76
296	Loc. Sub.	Woodlawn– Rand.	N	28	30.74	1.02	31.76	889.28	7.90	1:27– 1:55	1:40	80	71.14	4.8	152.45
300	Ex. Sub.	Floss.– Rand.	N	57	109.12	11.76	120.88	6,890.16	24.92	1:03– 2:00	......	70	482.31	4.2	507.70
302	Loc. Sub.	Woodlawn– Rand.	N	28	30.74	1.02	31.76	889.28	7.90	1:47– 2:15	2:00	80	71.14	4.8	152.45

Train No.	Train Classification	Direction of Run	Total Time of Run in Minutes	Ton Miles per Minute: Train C_1	Ton Miles per Minute: Load C_2P	Ton Miles per Minute: Total $C_1 + C_2P$	Total Ton Miles	Miles Run	Time: Leave	Time: Arrive	Observed Time at 39th St.	Estimated Watt-Hrs. per Ton Mile	Total Kilowatt-Hrs. on Run	Kilowatts per Ton Mile per Minute	Instantaneous Kilowatts
304	Ex. Sub. So. Chicago– Rand.	N	35	75.29	6.64	81.93	2,867.55	12.92	1:45–	2:20	2:12	70	200.73	4.2	344.11
294	Ex. Sub. So. Chicago– Rand.	N	35	75.29	5.98	81.27	2,844.4	12.91	1:05–	1:40	1:32	70	199.11	4.2	341.33
308	Loc. Sub. So. Chicago– Rand.	N	28	30.74	1.02	31.76	889.28	7.90	2:07–	2:35	2:21	80	71.14	4.8	152.45
310	Ex. Sub. Bl. Is.– Rand.	N	53	73.26	6.44	79.70	4,224.10	18.94	1:47–	2:40	2:33	70	259.69	4.2	334.74
314	Loc. Sub. Woodlawn – Rand.	N	28	30.74	.41	31.15	872.20	7.90	2:27–	2:55	2:40	80	69.78	4.8	149.52
316	Pass. M. C. Kens.– 12th	N	35	.....	.....	189.98	6,649.40	13.09	2:20–	2:55	2:55	40	265.98	2.4	455.95
320	Ex. Sub. So. Chicago – Rand.	N	35	75.29	5.97	81.26	2,843.10	12.91	2:25–	3:00	2:53	70	199.02	4.2	341.29
	Pass. Equipt. Burnside – 12th	N	40	.....	.....	136.92	5,417.70	10.53	2:32–	3:12	3:02	40	216.71	2.4	328.61
324	Loc. Sub. Woodlawn – Rand.	N	28	30.74	.41	31.15	872.20	7.90	2:47–	3:15	3:01	80	69.78	4.8	149.52
	Pass. Equipt. Burnside – 12th	N	40	.....	.....	78.58	3,143.20	10.53	2:35–	3:15	3:05	40	125.73	2.4	188.59
	Ft. I. C. Floss.– Rand.	N	105	.....	.....	259.76	27,274.90	24.92	1:35–	3:20	3:00	20	545.50	1.2	311.71
326	Ex. Sub. Harvey – Rand.	N	50	99.2	8.95	108.15	5,407.50	20.07	2:30–	3:20	3:22	70	378.53	4.2	454.23
330	Pass. M. C. Kens.– 12th	N	35	.....	.....	211.67	7,408.94	13.09	2:55–	3:30	3:21	40	296.36	2.4	508.01
332	Loc. Sub. Woodlawn – Rand.	N	28	30.74	.81	31.55	883.50	7.90	3:07–	3:35	3:26	80	70.68	4.8	151.44
336	Ex. Sub. So. Chicago – Rand.	N	35	75.29	4.98	80.27	2,809.45	12.91	3:05–	3:40	3:33	70	196.66	4.2	337.13
338	Loc. Sub. Woodlawn – Rand.	N	28	30.74	.41	31.15	872.20	7.90	3:27–	3:55	3:41	80	69.78	4.8	149.52
342	Ex. Sub. Bl. Is.– Rand.	N	50	77.33	6.08	83.41	4,170.50	18.94	3:10–	4:00	3:54	70	291.94	4.2	350.32
344	Add. Pass. Rand.	N	30	.....	.....	73.00	2,190.50	12.50	3:32–	4:02	......	40	87.60	2.4	175.20
346	Ft. I. C. Floss.– Fordham Y.	N	75	.....	.....	232.84	17,462.80	13.49	2:55–	4:10	......	20	349.26	1.2	279.41
	Ft. I. C. Floss.– Rand.	N	105	.....	.....	143.62	15,079.90	24.92	2:26–	4:11	3:51	20	301.60	1.2	172.34
348	Loc. Sub. Woodlawn – Rand.	N	28	30.74	.41	31.15	872.20	7.90	3:47–	4:15	4:00	80	69.78	4.8	149.52
350	Ex. Sub. So. Chicago – Rand.	N	35	91.76	5.81	97.57	3,414.95	12.91	3:45–	4:20	4:13	70	228.05	4.2	409.79
352	Loc. Sub. Burnside – 12th	N	40	.....	.....	115.30	4,612.10	10.53	3:40–	4:20	4:44	60	276.73	3.6	415.08
358	Pass. Freeport Div. I. C.– 12th	N	25	.....	.....	118.10	2,952.40	11.00	4:05–	4:30	......	40	118.10	2.4	283.44
	Eng. Burnside – 12th	N	40	.....	.....	24.88	995.10	10.53	3:54–	4:34	4:24	30	29.85	1.8	44.78
360	Loc. Sub. Woodlawn – Rand.	N	28	30.74	.41	31.15	872.20	7.90	4:07–	4:35	4:20	80	69.78	4.8	149.52
362	Ex. Sub. Floss.– Rand.	N	57	89.54	8.62	98.16	5,595.12	24.92	3:43–	4:40	4:35	70	391.73	4.2	412.27
364	Pass. M. C. Kens.– 12th	N	30	.....	.....	102.67	3,080.10	13.09	4:20–	4:50	4:42	40	123.20	2.4	246.41
366	Loc. Sub. Woodlawn – Rand.	N	28	59.01	1.56	60.57	1,695.96	7.90	4:27–	4:55	4:40	80	135.68	4.8	291.74
368	Ft. Freep't I. C.– Rand.	N	35	.....	.....	390.89	13,681.30	12.50	4:20–	4:55	......	40	547.25	2.4	948.14
372	Ex. Sub. So. Chicago – Rand.	N	35	59.01	4.68	63.69	2,229.15	12.91	4:25–	5:00	4:52	70	156.04	4.2	267.50

374	Loc. Sub.	Woodlawn – Rand.	N	28	59.01	.52	59.53	1,666.84	7.90	4:47–	5:15	5:00	80	133.35	4.8	285.74
376	Pass. I. C.	Floss.– 12th	N	60	...	.....	104.99	62,993.48	23.47	4:20–	5:20	......	40	251.98	2.4	251.98
378	Loc. Sub.	Burnside – 12th	N	40	....	. ...	27.38	1,095.12	10.53	4:40–	5:20	5:37	60	65.71	3.6	98.57
380	Ex. Sub.	Bl. Is.– Rand.	N	53	73.26	5.15	78.41	4,155.73	18.94	4:27–	5:20	5:11	70	290.90	4.2	329.32
384	Pass. Big 4	Floss.– 12th	N	47	... ..	.....	211.03	9,918.3	23.47	4:43–	5:30	6:47	40	396.73	2.4	506.47
386	Loc. Sub.	Woodlawn – Rand.	N	28	30.74	.41	31.15	872.2	7.90	5:07–	5:35	5:20	80	69.78	4.8	149.52
388	Ex. Sub.	So. Chicago – Rand.	N	35	111.37	5.98	117.35	4,107.25	12.91	5:05–	5:40	5:34	70	287.51	4.2	492.87
390	Ex. Sub.	67th – Rand.	N	18	70.73	.00	70.73	1,273.14	8.40	5:32–	5:50	5:37	70	89.12	4.2	297.07
	Ft. I. C.	Floss.– Rand.	N	105	... ..	.....	223.86	23,535.9	24.92	3:07–	5:52	5:32	20	470.72	1.2	268.63
392	Ex. Sub.	67th – Rand.	N	18	70.73	.00	70.73	1,273.14	8.40	5:37–	5:55	5:41	70	89.12	4.2	297.07
394	Loc. Sub.	Woodlawn – Rand.	N	28	30.74	.20	30.94	866.32	7.90	5:27–	5:55	5:40	80	69.31	4.8	148.51
398	Ex. Sub.	Floss.– Rand.	N	60	101.68	6.31	107.99	6,479.40	24.92	5:00–	6:00	6:01	70	453.56	4.2	453.56
400	Pass. M. C.	Kens.– 12th	N	35	... ..	.....	132.88	4,650.9	13.09	5:25–	6:00	6:01	40	186.04	2.4	318.91
	Eng. 921	Burnside – Rand.	N	45	... ..	.....	25.16	1,132.1	11.98	5:19–	6:04	5:49	30	33.96	1.8	45.29
402	Ex. Sub.	67th – Rand.	N	18	70.73	.00	70.73	1,273.14	8.40	5:54–	6:12	6:03	70	89.12	4.2	297.07
410	Loc. Sub.	Woodlawn– Rand.	N	28	87.29	.39	87.68	2,455.04	7.90	5:47–	6:15	6:01	80	196.43	4.8	420.86
412	Pass. W. C.	– 12th	N	25	... ..	.....	118.10	2,952.4	11.00	5:50–	6:15	......	40	118.10	2.4	283.44
414	Loc. Sub.	Kens.– Rand.	N	52	56.98	.25	57.23	2,975.96	14.54	5:28–	6:20	6:09	60	178.56	3.6	206.03
416	Ex. Sub.	So. Chicago – Rand.	N	35	91.76	2.08	93.84	3,284.40	12.91	5:45–	6:20	6:12	70	229.91	4.2	394.13
418	Ex. Sub.	Bl. Is.– Ran.	N	71	66.96	.60	67.56	4,796.76	18.94	5:13–	6:24	6:15	70	335.78	4.2	283.75
	Work Tr.	Burnside – 26th	N	36	... ..	.....	39.65	1,427.5	8.95	5:49–	6:25	6:16	40	57.10	2.4	95.16
422	Loc. Sub.	Woodlawn – Rand.	N	28	71.92	.33	72.25	2,023.0	7.90	6:07–	6:35	6:20	80	161.84	4.8	346.80
426	Pass. C. C.& L	Riverdale–Rand.	N	40	... ..	.....	140.77	5,603.1	15.77	6:00–	6:40	6:40	40	224.12	2.4	337.85
424	Ex. Sub.	Bl. Is.– Rand.	N	55	69.19	1.18	70.37	3,870.35	18.94	5:45–	6:40	6:33	70	270.92	4.2	295.55
434	Loc. Sub.	So. Chicago – Rand.	N	45	71.92	1.30	73.22	3,294.90	12.91	6:10–	6:55	6:40	60	197.69	3.6	263.59
438	Ex. Sub.	Harvey – Rand.	N	52	96.70	2.23	98.93	5,144.36	20.07	6:13–	7:05	6:56	70	360.10	4.2	415.51
440	Loc. Sub.	So. Chicago – Rand.	N	45	71.92	1.30	73.22	3,294.90	12.91	6:40–	7:25	7.09	60	197.69	3.6	263.59
442	Pass. I. C.	Floss.– 12th	N	55	... ..	.....	132.46	7,285.1	23.47	6:33–	7:28	7:21	40	291.40	2.4	317.90
446	Loc. Sub.	Bl. Is.– Rand.	N	71	54.94	1.94	56.88	4,038.48	18.94	6:34–	7:45	7:31	60	242.31	3.6	204.77
448	Ex. Sub.	So. Chicago – Rand.	N	35	111.37	7.47	118.84	4,159.40	12.91	7:10–	7:45	7:37	70	291.16	4.2	499.13
452	Pass. M. C.	Kens.– 12th	N	32	... ..	.....	174.52	5.584.8	14.54	7:18–	7:50	8:05	40	223.39	2.4	418.87
	Eng.	Burnside – 12th	N	40	... ..	.....	24.88	995.1	10.53	7:14–	7:54	7:44	30	29.85	1.8	44.78
454	Ex. Sub.	Floss.– Rand.	N	65	117.40	7.47	124.87	8,116.55	24.92	6:50–	7:55	7:45	70	568.16	4.2	524.45
458	Loc. Sub.	So. Chicago – Rand.	N	45	71.92	1.95	73.87	3,324.15	12.91	7:15–	8:00	7:45	60	199.45	3.6	265.73
462	Loc. Sub.	Bl. Is.– Rand.	N	65	71.92	3.25	75.17	4,886.05	18.94	7:10–	8:15	8:02	60	292.16	3.6	268.61
	Ft. M. C.	Kens. – Rand.	N	65	... ..	....	54.69	3,555.0	14.54	7:23–	8:28	8:08	30	106.65	1.8	98.44
464	Loc. Sub.	So. Chicago – Rand.	N	45	59.01	1.30	60.31	2,713.95	12.91	7:45–	8:30	8:16	60	162.84	3.6	217.12
466	Pass. M. C.	Kens.– 12th	N	35	... ..	.....	227.13	7,949.6	13.09	7:55–	8:30	8:20	40	317.98	2.4	545.11
468	Pass. Big 4	Floss.– 12th	N	47	... ..	.....	132.42	6,223.9	23.47	7:53–	8:40	8:31	40	248.96	2.4	317.81
470	Loc. Sub.	Bl. Is. – Rand.	N	65	87.29	1.56	88.85	5,775.25	18.94	55:–	79:0	8:48	60	346.51	3.6	319.86

Train No.	Train Classification		Direction of Run	Total Time of Run in Minutes	Ton Miles per Minute			Total Ton Miles	Miles Run	Time		Observed Time at 39th St.	Estimated Watt-Hrs. per Ton Mile	Total Kilowatt-Hrs. on Run	Kilowatts per Ton Mile per Minute	Instantaneous Kilowatts
					Train C_1	Load C_2P	Total $C_1 + C_2P$			Leave	Arrive					
472	Pass. M. C.	Kens.– –12th.	N	35	.....	.....	195.98	6,859.2	13.09	8:35–	9:10	9:02	40	274.37	2.4	470.35
482	Loc. Sub.	So. Chicago – Rand.	N	45	59.01	1.56	60.57	2,725.65	12.91	8:45–	9:30	9:16	60	163.54	3.6	218.05
484	Pass. I. C.	Floss.– 12th.	N	50	.....	.....	193.96	9,697.8	23.47	8:40–	9:30	9:20	40	387.91	2.4	465.50
	Equipt.	Burnside– 12th.	N	40	.....	.....	58.30	2,331.9	10.53	9:01–	9:41	9:31	40	93.28	2.4	139.92
486	Pass.	Freeport Div. I.C.– 12th	N	25	.....	.....	160.47	4,011.7	11.00	9:30–	9:55	......	40	160.47	2.4	385.13
490	Loc. Sub.	Floss.– Rand.	N	75	67.15	3.55	70.70	5,302.50	24.92	8:45–	10:00	9:49	60	318.15	3.6	254.52
492	Pass.	W. C.– 12th	N	25	.....	.....	118.10	2,952.4	11.00	9:35–	10:00	......	40	118.10	2.4	283.44
	Ft. M. C.	Kens.– Rand.	N	65	.....	.....	309.70	20,130.6	14.54	9:23–	10:28	10:08	20	402.61	1.2	371.64
494	Loc. Sub.	So. Chicago – Rand.	N	45	59.01	1.04	60.05	2,702.25	12.91	9:45–	10:30	10:15	60	162.14	3.6	216.18
	Ft I. C.	Floss.– Rand.	N	105	.....	.....	190.93	20,048.1	24.92	8:55–	10:40	10:20	20	400.96	1.2	229.12
	Ft. I. C.	Floss.– Rand.	N	105	.....	.....	371.31	38,987.3	24.92	9:09–	10:54	10:34	20	779.75	1.2	445.57
496	Loc. Sub.	Bl. Is.– Rand.	N	65	59.01	2.60	61.61	4,004.65	18.94	9:55–	11:00	10:46	60	240.28	3.6	221.80
	Eng.	Burnside – Rand.	N	45	.....	.....	25.15	1,132.1	11.98	9:29–	11:14	9:59	30	33.96	1.8	45.27
500	Ft. I. C.	Floss.– Rand.	N	120	.....	.....	247.89	26,028.9	24.92	9:30–	11:30	11:00	20	594.94	1.2	297.47
498	Loc. Sub.	So. Chicago – Rand.	N	45	59.01	1.04	60.05	2,702.25	12.91	10:45–	11:30	11:16	60	162.14	3.6	216.18
502	Loc. Sub.	Floss.– Rand.	N	70	73.26	1.29	74.55	5,218.50	24.92	10:45–	11:55	11:40	60	313.11	3.6	268.48

APPENDIX B

24-HOUR OBSERVATION OF TRAIN MOVEMENT ON ILLINOIS CENTRAL TERMINAL PAST 39TH STREET

	Schedule Time		Time Passed		Service	Number of Cars							Eng. No.	% Full	Remarks
	N.	S.	N.	S.		Coaches Bag. & Exp.	Suburban	Pullman	Box	Stock	All Other Cars				
12 MID.	01	..	03	..	L. .... So. Chicago	..	4	..	..	..	..	......	1412	30	
	..	04	..	05	L. .... So. Chicago	..	4	..	..	..	..	......	1418	50	
	..	14	..	14	P. .... M. C.	8	..	2	..	..	..	N. Y. C.	8450	..	
	..	..	16	..	F. .... M. C.	..	..	..	18	..	..	N. Y. C.	8282	..	
	16	..	18	..	L. .... Kensington	..	4	..	..	..	..	......	1405	5	
	..	..	..	23	F. .... I. C.	..	..	..	42	..	1	......	598	..	
	..	24	..	27	L. .... Flossmoor	..	4	..	..	..	..	......	1426	50	
	36	..	35	..	L. .... So. Chicago	..	6	..	..	..	..	......	1423	15	
	..	..	..	36	Eng.	..	..	..	..	..	..	......	559	..	
	..	44	..	46	L. .... So. Chicago	..	4	..	..	..	..	......	1412	50	
	..	59	..	1:01	L. .... Woodlawn	..	4	..	..	..	..	......	1405	10	
1 A. M.	..	..	..	08	F. .... M. C.	..	..	..	59	..	4	N. Y. C.	8261	..	
	..	14	..	14	L. .... Grand Crossing	..	4	..	..	..	..	......	1423	50	
	..	..	..	45	Equipment.	..	4	..	..	..	..	......	109	..	Empty
	..	..	..	46	Equipment.	9	..	4	..	..	..	......	92	..	Empty
	..	..	..	50	F. .... I. C.	..	..	..	44	..	1	......	80	..	
2 A. M.	..	..	08	..	F. .... I. C.	..	..	..	52	..	15	......	642	..	
	..	24	..	24	F. .... I. C.	..	..	..	35	1	27	......	631	..	
	..	..	38	..	Equipment .... I. C.	12	..	1	..	..	..	......	92	..	Empty
	..	56	..	59	P. .... I. C.	7	..	1	..	..	..	......	1048	..	
3 A. M.	..	08	..	08	P. .... M. C.	4	..	..	..	..	..	......	......	..	
	..	..	16	..	Equipment. .... I. C.	..	2	..	..	..	..	......	......	..	Empty
	..	..	37	..	F. .... I. C.	..	..	..	17	..	1	......	593	..	
	52	..	45	..	F. .... I. C.	..	..	..	6	..	2	......	1047	..	
A. M.	12	..	06	..	F. .... I. C.	..	..	..	5	..	1	......	582	..	
	..	..	16	..	F. .... C. C. & L.	..	..	..	11	..	1	......	213	..	
	..	..	..	32	Eng. .... I. C.	..	..	..	..	..	..	......	592	..	
	32	..	5:21	..	F. .... I. C.	..	..	..	6	1	1	......	588	..	

	Schedule Time		Time Passed		Service	Number of Cars							Eng. No.	% Full	Remarks
	N.	S.	N.	S.		Coaches Bag. & Exp.	Suburban	Pullman	Box	Stock	All Other Cars				
	..	..	38	..	F. .... M. C.	..	..	..	29	..	1	N. Y. C.	8272	..	
5 A. M.	02	..	36	..	F. .... I. C.	..	..	..	12	..	3	....	634	..	
	31	..	31	..	L. .... Homewood	..	6	..	..	..	..	....	1425	10	
	..	..	40	..	F. .... I. C.	..	..	..	23	..	45	....	80	..	
	37	..	48	..	F. .... N. Y. C.	..	..	..	21	..	1	N. Y. C.	8263	..	
	..	39	..	45	L. .... Harvey.	..	6	..	..	..	..	....	1422	10	
	..	..	49	..	F. .... I. C.	..	..	..	34	..	1	....	940	..	
	..	..	54	..	F. .... I. C.	..	..	..	13	..	2	....	584	..	
6 A. M.	..	04	..	07	L. .... Blue Island	..	4	..	..	..	..	....	1424	20	
	11	..	11	..	L. .... So. Chicago	..	4	..	..	..	..	....	1432	25	
	..	14	..	14	L. .... So. Chicago	..	4	..	..	..	..	....	1425	6	
	20	..	20	..	P .... I. C.	8	..	1	..	..	..	....	1047	..	
	..	21	..	21	L. .... Burnside	..	9	..	..	..	..	....	1430	30	
	..	..	..	23	Eng.	..	..	..	..	..	..	....	562	..	
	31	..	32	..	L. .... Blue Island	..	5	..	..	..	..	....	1415	85	
	31	..	8:45	..	F. .... I. C.	..	..	..	4	..	29	....	68	..	Largely coal
	40	..	47	..	P. .... C. C. & L.	2	..	2	..	..	..	C. C. & L.	116	..	
	40	..	46	..	L. .... Burnside	..	4	..	..	..	..	....	1414	45	
	..	49	..	50	L. .... Flossmoor	..	6	..	..	..	..	....	1432	20	
7 A. M.	00	..	01	..	P. .... C. C. C. & St. L.	5	..	3	..	..	..	I. C.	1036	..	
	01	..	01	..	L .... Homewood	..	4	..	..	..	..	....	1429	30	
	02	..	02	..	Exp .... So. Chicago.	..	4	..	..	..	..	....	1416	100	
	06	..	05	..	P. .... M. C.	2	..	3	..	..	..	....	......	..	
	..	..	06	..	Eng	..	..	..	..	..	..	....	......	68	
	11	..	11	..	Exp .... Blue Island	..	4	..	..	..	..	....	1408	100	
	12	..	11	..	L. .... Burnside	..	2	..	..	..	..	....	1432	25	Side door cars
	18	..	18	..	P. .... I. C.	4	..	4	..	..	..	....	1008	..	
	..	08	..	09	Exp .... So. Chicago.	..	4	..	..	..	..	....	1427	20	
	..	19	..	18	L. .... Woodlawn	..	4	..	..	..	..	....	1415	16	
	21	..	21	..	L. .... Burnside	..	2	..	..	..	..	....	1407	60	Side door cars
	..	21	..	18	P. .... M. C.	7	..	..	..	..	..	N. Y. C.	8455	..	

	21	..	23	..	P. . . . . M. C.	8	..	5	..	..	..	N. Y. C.	7959	..	
	..	..	..	23	F. . . . . I. C.	..	..	..	2	..	2	....	......	..	
	22	..	22	..	Exp. . . . . So. Chicago	..	5	..	..	..	..	....	1425	85	
	..	..	25	..	F. . . . . C. C. & L.	..	..	..	10	..	1	C. C. & L.	215	..	
	26	..	26	..	L. . . . . Burnside	..	4	..	..	..	..	....	1428	25	
	28	..	7	..	Exp. . . . . Homewood	..	4	..	..	..	..	....	1440	85	
	..	28	..	29	Exp. . . . . Blue Island	..	5	..	..	..	..	....	1416	10	
	31	..	31	..	L. . . . . Burnside	..	5	..	..	..	..	....	1406	65	
	32	..	32	..	Exp. . . . . So. Chicago	..	5	..	..	..	..	....	1410	100	
	35	..	34	..	P. . . . . . . C. C. C. & St. L.	2	..	3	..	..	..	I. C.	1	S	
	36	..	35	..	L. . . . . Burnside	..	4	..	..	..	..	....	1497	70	
	37	..	37	..	Exp. . . . . Harvey	..	6	..	..	..	..	....	1422	125	
	..	39	..	40	L. . . . . Woodlawn	..	4	..	..	..	..	....	1414	15	
	41	..	41	..	L. . . . . Burnside	..	3	..	..	..	..	....	1421	125	Side open cars
	43	..	43	..	Exp. . . . . So. Chicago	..	6	..	..	..	..	....	1437	110	
	..	..	..	44	Eng.	..	..	..	..	..	..	....	1419	..	
	46	..	46	..	L. . . . . Burnside	..	4	..	..	..	..	....	1404	85	
	47	..	46	..	Exp. . . . . Flossmoor	..	6	..	..	..	..	....	1433	115	
	..	48	..	48	Exp. . . . . So. Chicago	..	5	..	..	..	..	....	1429	10	
	51	..	50	..	L. . . . . Burnside	..	4	..	..	..	..	....	296	80	
	..	..	..	52	Eng.	..	..	..	..	..	..	....	68	..	
	53	..	..	..	Exp. . . . . Burnside	..	4	..	..	..	..	....	1420	100	
	..	..	55	..	F. . . . . M. C.	..	..	..	35	..	..	N. Y. C.	8269	..	
	56	..	55	..	L. . . . . Woodlawn	..	4	..	..	..	..	....	1415	90	
	..	..	..	57	Exp. . . . . 67th St.	..	6	..	..	..	..	....	1440	0	
	58	..	54	..	Exp. . . . . Blue Island	..	6	..	..	..	..	....	1424	110	
	..	59	..	8:00	L. . . . . Woodlawn	..	4	..	..	..	..	....	1408	15	
8 A. M.	01	..	00	..	L. . . . . Burnside	..	2	..	..	..	..	....	1417	75	
	02	..	02	..	Exp. . . . . So. Chicago	..	6	..	..	..	..	....	1418	140	
	06	..	..	..	L. . . . . Burnside	..	4	..	..	..	..	....	1402	80	
	07	..	06	..	Exp. . . . . Burnside	..	5	..	..	..	..	....	1413	100	
	...	08	..	14	Exp. . . . . Harvey	..	6	..	..	..	..	....	1425	10	
	..	..	..	09	. . . . M. C.	1	..	..	..	..	..	N. Y. C.	8365	..	Horse car
	11	..	10	..	L. . . . . Burnside	..	2	..	..	..	..	....	1434	90	Side open cars
	12	..	11	..	Exp. . . . . Burnside	..	5	..	..	..	..	....	1436	150	
	16	..	16	..	L. . . . . Woodlawn	..	4	..	..	..	..	....	1414	60	
	17	..	18	..	Exp. . . . . Flossmoor	..	6	..	..	..	..	....	1438	135	
	..	19	..	21	L. . . . . Woodlawn	..	2	..	..	..	..	....	1410	10	
	21	..	20	..	L. . . . . Burnside	..	2	..	..	..	..	....	1405	60	Side open cars
	22	..	21	..	Exp. . . . . So. Chicago	..	5	..	..	..	..	....	1427	110	

	Schedule Time		Time Passed		Service	Number of Cars							Eng. No.	% Full	Remarks
	N.	S.	N.	S.		Coaches Bag. & Exp.	Suburban	Pullman	Box	Stock	All Other Cars				
	23	..	22	..	Exp. . . . . Flossmoor	..	3	..	..	..	..	. . . .	1426	90	
	26	..	25	..	L. . . . . Burnside	..	4	..	..	..	..	. . . .	1430	30	
	27	..	26	..	Exp. . . . . Grand Crossing	..	5	..	..	..	..	. . . .	1423	85	
	..	28	..	31	Exp. . . . . So. Chicago	..	6	..	..	..	..	. . . .	1422	15	
	31	..	32	..	L. . . . . Woodlawn	..	4	..	..	..	..	. . . .	1435	40	
	32	..	30	..	Exp. . . . . Blue Island	..	5	..	..	..	..	. . . .	1409	100	
	36	..	41	..	P. . . . . M. C.	4	..	5	..	..	..	N. Y. C.	7965	..	
	37	..	..	..	Exp. . . . . 67th St.	..	4	..	..	..	..	. . . .	1440	75	
	..	37	..	37	P. . . . . I. C.	5	..	..	..	..	..	. . . .	1969	..	
	..	39	..	42	L. . . . . Woodlawn	..	2	..	..	..	..	. . . .	1437	25	
	41	..	41	..	L. . . . . Woodlawn	..	4	..	..	..	..	. . . .	1408	75	
	42	..	44	..	Exp. . . . . So. Chicago	..	6	..	..	..	..	. . . .	1412	90	
	..	44	..	44	P. . . . . C. C. & L.	3	..	..	..	..	..	C. C. & L.	55	..	
	..	50	..	49	Exp. . . . . Blue Island	..	4	..	..	..	..	. . . .	1404	10	
	51	..	50	..	L. . . . . Grand Crossing	..	4	..	..	..	..	. . . .	1419	35	
	52	..	51	..	Exp. . . . . Flossmoor	..	6	..	..	..	..	. . . .	1432	100	
	..	53	..	53	P. . . . . M. C.	2	..	4	..	..	..	N. Y. C.	8454	..	
	..	..	..	56	Eng.	..	..	..	..	..	..	. . . .	296	..	
	..	59	..	9:01	L. . . . . Woodlawn	..	2	..	..	..	..	. . . .	1407	10	
9 A. M.	01	..	00	..	L. . . . . Woodlawn	..	2	..	..	..	..	. . . .	1410	30	
	02	..	00	..	Exp. . . . . So. Chicago	..	5	..	..	..	..	. . . .	1429	125	
	06	..	07	..	P. . . . . I. C.	3	..	2	..	..	..	. . . .	1035	..	
	..	08	..	09	P. . . . . C. C. C. & St. L.	4	..	2	..	..	..	. . . .	2007	..	
	..	08	..	09	Exp. . . . . So. Chicago	..	4	..	..	..	..	. . . .	1434	10	
	12	..	12	..	Exp. . . . . Blue Island	..	5	..	..	..	..	. . . .	1416	100	
	..	..	14	..	F. . . . . I. C.	..	..	..	23	1	24	. . . .	634	..	23 loaded coal ⅔ boxes empty
	..	19	..	20	L. . . . . Woodlawn	..	2	..	..	..	..	. . . .	1412	10	
	21	..	21	..	L. . . . . Woodlawn	..	2	..	..	..	..	. . . .	1437	60	
	..	..	21	..	F. . . . . I. C.	..	..	..	19	2	39	. . . .	75	..	Mostly empty
	..	27	..	28	Exp. . . . . Flossmoor	..	4	..	..	..	..	. . . .	1424	35	

	32	..	32	..	Exp.	So. Chicago	..	6	..	..	..	..	....	1422	90	
	..	39	..	40	L.	Woodlawn	..	2	..	..	..	..	....	1430	10	
	41	..	40	..	L.	Woodlawn	..	2	..	..	..	..	....	1407	25	
	48	..	53	..	P.	I. C.	3	..	..	..	..	..	....	1966	..	
	..	48	..	46	P.	I. C.	2	..	3	..	..	..	....	1048	..	
	..	48	..	49	Exp.	So. Chicago	..	4	..	..	..	..	....	1410	25	
	52	..	52	..	Exp.	Harvey	..	5	..	..	..	..	....	1425	85	
	..	59	..	10:02	L.	Woodlawn	..	2	..	..	..	..	....	1435	10	
10 A.M.	01	..	00	..	L.	Woodlawn	..	2	..	..	..	..	....	1412	35	
	..	08	..	09	Exp.	Blue Island	..	4	..	..	..	..	....	1414	50	
	..	10	..	11	P.	I. C.	4	..	1	..	..	..	....	1008	..	
	12	..	11	..	Exp.	So. Chicago	..	4	..	..	..	..	....	1434	100	
	..	19	..	19	L.	Woodlawn	..	2	..	..	..	..	....	1416	10	
	21	..	20	..	L.	Woodlawn	..	2	..	..	..	..	....	1430	25	
	..	28	..	30	Exp.	So. Chicago	..	5	..	..	..	..	....	1438	25	
	33	..	..	..	Exp.	Blue Island	..	4	..	..	..	..	....	1404	90	
	..	39	..	40	L.	Woodlawn	..	2	..	..	..	..	....	1407	20	
	..	39	..	39	P.	M. C.	4	..	4	..	..	..	N. Y. C.	7959	..	
	41	..	41	..	L.	Woodlawn	..	2	..	..	..	..	....	1435	40	
	..	..	..	46	F.	M. C.	..	..	..	1	..	..	N. Y. C.	8288	..	
	46	..	53	..	L.	So. Chicago	2	..	..	..	..	..	....	296	0	
	..	48	..	48	Exp.	Harvey	..	4	..	..	..	..	....	1417	50	
	53	..	51	..	Exp.	So. Chicago	..	4	..	..	..	..	....	1410	75	
	..	..	..	52	Eng.		..	..	..	..	..	..	....	77	..	
	..	59	..	11:00	L.	Woodlawn	..	2	..	..	..	..	....	1430	10	
11 A.M.	01	..	00	..	L.	Woodlawn	..	2	..	..	..	..	....	1416	50	
	..	08	..	..	Exp.	So. Chicago	..	4	..	..	..	..	....	1404	60	
	11	..	38	..	F.	M. C.	..	..	..	25	..	5	N. Y. C.	8377	..	Mostly loaded, coal, coke, & refrigerator
	12	..	11	..	Exp.	Flossmoor	..	4	..	..	..	..	....	1424	100	
	..	14	..	14	F.	I. C.	..	..	..	1	..	..	....	549	..	
	18	..	23	..	P.	I. C.	5	..	5	..	..	..	....	....	..	
	..	19	..	19	L.	Woodlawn	..	2	..	..	..	..	....	1434	10	
	21	..	..	..	L.	Woodlawn	..	2	..	..	..	..	....	1407	50	
	..	28	..	29	Exp.	Blue Island	..	4	..	..	..	..	....	1420	80	
	..	..	30	..	F.	I. C.	..	..	..	13	..	16	....	77	..	All loaded: coal & lumber
	32	..	32	..	Exp.	So. Chicago	..	5	..	..	..	..	....	1438	80	
	..	39	..	..	L.	Woodlawn	..	2	..	..	..	..	....	1421	15	

	Schedule Time		Time Passed		Service	Number of Cars							Eng. No.	% Full	Remarks
	N.	S.	N.	S.		Coaches Bag. & Exp.	Suburban	Pullman	Box	Stock	All Other Cars				
	41	..	40	..	L. . . . . .Woodlawn	..	2	..	..	..	..	. . . .	1430	25	
	..	..	..	40	F. . . . . .I. C.	..	..	..	42	5	23	. . . .	{ 634 {1497	.. ..	Mostly empty
	..	..	..	42	F. . . . . .M. C.	..	..	..	1	..	..	N. Y. C.	8260	..	
	..	48	..	50	Exp. . . . . .So. Chicago	..	4	..	..	..	..	. . . .	1402	70	
	52	..	51	..	Exp. . . . . .Blue Island	..	4	..	..	..	..	. . . .	1414	60	
	..	..	52	..	F. . . . . .I. C.	..	..	..	25	..	..	. . . .	572	..	Refrigerators
	..	..	58	..	F. . . . . .M. C.	..	..	..	29	..	..	N. Y. C.	8284	..	
	..	59	..	12:00	L. . . . . .Woodlawn	..	2	..	..	..	..	. . . .	1416	40	
12 M.	01	..	00	..	L. . . . . .Woodlawn	..	2	..	..	..	..	. . . .	1434	20	
	..	08	..	08	Exp. . . . . .Flossmoor	..	5	..	..	..	..	. . . .	1427	60	
	12	..	11	..	Exp. . . . . .So. Chicago	..	5	..	..	..	..	. . . .	1404	75	
	..	19	..	20	L. . . . . .Woodlawn	..	2	..	..	..	..	. . . .	1438	15	
	21	..	..	..	L. . . . . .Woodlawn	..	2	..	..	..	..	. . . .	1421	20	
	..	28	..	30	Exp. . . . . .So. Chicago	..	4	..	..	..	..	. . . .	1410	75	
	32	..	32	..	Exp. . . . . .Harvey	..	4	..	..	..	..	. . . .	1417	100	
	..	..	..	33	Golf special.	..	2	..	..	..	..	. . . .	1428	25	
	..	39	..	41	L. . . . . .Woodlawn	..	2	..	..	..	..	. . . .	1431	15	
	41	..	40	..	L. . . . . .Woodlawn	..	2	..	..	..	..	. . . .	1416	20	
	..	..	..	44	Equipment.	9	..	3	..	..	1	. . . .	296	..	Empty
	..	48	..	50	Exp . . . . .Blue Island	..	4	..	..	..	..	. . . .	1419	50	
	..	..	48	..	Equipment.	..	..	1	..	..	..	. . . .	1047	..	
	52	..	52	..	Exp. . . . . .So. Chicago	..	..	4	..	..	..	. . . .	1402	65	
	..	59	..	1:01	L. . . . . .Woodlawn	..	2	..	..	..	..	. . . .	1406	15	
1 P. M.	01	..	00	..	L. . . . . .Woodlawn	..	2	..	..	..	..	. . . .	1438	30	
	06	..	06	..	P. . . . . .M. C.	3	..	1	..	..	..	N. Y. C.	7954	..	
	..	07	..	08	P. . . . . C. C. C. & St. L.	3	..	2	..	..	..	. . . .	1	..	
	..	08	..	..	Exp. . . . . .So. Chicago	..	..	..	..	..	..	. . . .	1421	40	
	11	..	21	..	P. . . . . .I. C.	7	..	..	..	..	..	. . . .	2	..	
	12	..	11	..	Exp. . . . . .Blue Island	..	4	..	..	..	..	. . . .	1420	60	
	..	19	..	20	L . . . . Woodlawn	..	2	..	..	..	..	. . . .	1404	15	

	21	..	20	..	L.	Woodlawn	..	2	..	..	..	..	....	1413	20	
	..	23	..	22	P.	M. C.	2	..	1	..	..	..	N. Y. C.	8133	..	
	..	..	25	..	F.	M. C.	..	..	..	6	..	..	N. Y. C.	8283	..	
	..	28	..	28	Exp.	Harvey	..	4	..	..	..	..	....	1432	75	
	..	28	..	29	F.	I. C.	..	..	..	68	..	..	....	....	..	E'ty refrigerators
	32	..	32	..	Exp	So. Chicago	..	4	..	..	..	..	....	1410	90	
	..	..	..	33	Eng.		..	..	..	..	..	..	....	572	..	
	..	39	..	41	L	Woodlawn	..	2	..	..	..	..	....	1417	30	
	41	..	40	..	L.	Woodlawn	..	2	..	..	..	..	....	1406	25	
	..	48	..	50	Exp.	So. Chicago	..	4	..	..	..	..	....	1402	90	
	52	..	..	..	Exp.	Flossmoor	..	5	..	..	..	..	....	1427	120	
	..	59	..	2:01	L.	Woodlawn	..	2	..	..	..	..	....	1420	10	
2 P. M.	01	..	00	..	L.	Woodlawn	..	2	..	..	..	..	....	1404	25	
	..	..	..	06	Equipment		10	..	..	..	..	..	....	92	..	
	..	06	..	10	Exp.	Blue Island	..	4	..	..	..	..	....	1413	60	
	..	..	10	..	F.	M C.	..	..	..	8	..	1	N. Y. C.	8647	..	
	13	..	12	..	Exp.	So. Chicago	..	4	..	..	..	..	....	1421	100	
	..	19	..	20	L.	Woodlawn	..	2	..	..	..	..	....	1415	10	
	21	..	21	..	L	Woodlawn	..	2	..	..	..	..	....	1417	25	
	..	28	..	30	Exp.	So. Chicago	..	4	..	..	..	..	....	1406	80	
	32	..	33	..	Exp.	Blue Island	..	4	..	..	..	..	....	1419	100	
	..	..	..	36	P (Special)	I. C.	4	..	2	..	..	..	....	1047	80	
	..	39	..	42	L.	Woodlawn	..	2	..	..	..	..	....	1427	10	
	41	..	40	..	L.	Woodlawn	..	2	..	..	..	..	....	1420	10	
	46	..	55	..	P.	M. C.	6	..	3	..	..	..	N. Y. C.	7964	..	
	..	48	..	48	Exp.	Flossmoor	..	4	..	..	..	..	....	1429	100	
	53	..	53	..	Exp.	So. Chicago	..	4	..	..	..	..	....	1402	90	
	..	59	..	3:01	L.	Woodlawn	..	2	..	..	..	..	....	1422	10	
3 P. M.	..	..	00	..	F.	I. C.	..	..	..	29	..	..	....	634	..	
	01	..	01	..	L.	Woodlawn	..	2	..	..	..	..	....	1415	10	
	..	..	..	02	Equipment		10	..	..	..	..	..	....	92	..	Empty
	..	..	05	..	Equipment		..	2	2	1	..	..	....	826	..	
	..	08	..	10	Exp.	So. Chicago	..	5	..	..	..	..	....	1435	90	
	..	09	..	23	P.	M. C.	5	..	4	..	..	..	N. Y. C.	7965	..	
	12	..	22	..	Exp.	Harvey	..	5	..	..	..	..	....	1432	100	
	..	19	..	21	L.	Woodlawn	..	2	..	..	..	..	....	1417	15	
	21	..	26	..	L.	Woodlawn	..	2	..	..	..	..	....	1427	20	
	21	..	21	..	P.	M. C.	5	..	5	..	..	..	N. Y. C.	8452	..	
	..	28	..	30	Exp.	Blue Island	..	4	..	..	..	..	....	1421	90	
	33	..	33	..	Exp.	So. Chicago	..	4	..	..	..	..	....	1406	75	

	Schedule Time		Time Passed		Service	Number of Cars							Eng. No.	% Full	Remarks
	N.	S.	N.	S.		Coaches Bag. & Exp.	Suburban	Pullman	Box	Stock	All Other Cars				
	..	39	..	41	L. . . . . Woodlawn	..	2	..	..	..	..	....	1419	10	
	41	..	41	..	L. . . . . Woodlawn	..	2	..	..	..	..	....	1422	10	
	..	..	51	..	F. . . . . I. C.	..	..	..	11	..	..	....	586	..	Loaded.
	..	48	..	50	Exp. . . . . So. Chicago	..	4	..	..	..	..	....	1407	70	
	..	..	..	49	Eng.	..	..	..	..	..	..	....	1430	..	
	..	52	..	54	P. . . . . I. C.	7	..	..	..	..	..	....	1966	..	
	52	..	54	..	Exp. . . . . Blue Island	..	4	..	..	..	..	....	1413	90	
	..	58	..	58	Exp. . . . . Flossmoor	..	5	..	..	..	..	....	1440	50	
	..	59	..	4:00	L. . . . . Woodlawn	..	4	..	..	..	..	....	1414	10	
4 P. M.	01	..	00	..	L . . . . . Woodlawn	..	2	..	..	..	..	....	1417	10	
	..	08	..	10	Exp. . . . . Blue Island	..	5	..	..	..	..	....	1415	50	
	10	..	44	..	L. . . . . Burnside	..	9	..	..	..	..	....	1430	..	Shop train
	12	..	13	..	Exp. . . . . So. Chicago	..	5	..	..	..	..	....	1435	70	
	..	19	..	19	L. . . . . Woodlawn	..	4	..	..	..	..	....	1420	20	
	21	..	20	..	L. . . . . Woodlawn	..	2	..	..	..	..	....	1419	10	
	..	..	24	..	Eng.	..	..	..	..	..	..	....	1001	..	
	..	28	..	29	Exp. . . . . So. Chicago	..	6	..	..	..	..	....	1406	80	
	32	..	35	..	Exp. . . . . Flossmoor	..	4	..	..	..	..	....	1429	110	
	..	38	..	40	Exp. . . . . Kensington	..	4	..	..	..	..	....	1422	80	
	..	39	..	41	L. . . . . Woodlawn	..	2	..	..	..	..	....	1434	30	
	41	..	40	..	L. . . . . Woodlawn	..	4	..	..	..	..	....	1414	30	
	43	..	42	..	P. . . . . M. C.	2	..	1	..	..	..	N. Y. C.	8212	..	
	..	..	..	44	Eng.	..	..	..	..	..	..	....	586	..	
	..	48	..	52	Exp. . . . . Blue Island	..	4	..	..	..	..	....	1436	100	
	52	..	52	..	Exp. . . . . So. Chicago	..	4	..	..	..	..	....	1407	90	
	..	58	..	5:00	Exp. . . . . So. Chicago	..	5	..	..	..	..	....	1439	80	
	..	59	..	5:00	L. . . . . Woodlawn	..	2	..	..	..	..	....	1402	40	
5 P. M.	01	..	00	..	L. . . . . Woodlawn	..	4	..	..	..	..	....	1420	10	
	..	03	..	03	P. . . . . M. C.	3	..	1	..	..	..	N. Y. C.	8223	..	
	..	08	..	09	Exp. . . . . Harvey	..	5	..	..	..	..	....	1424	90	
	..	08	..	08	P. . . . . M. C.	6	..	2	..	..	..	N. Y. C.	7954	..	

	..	09	..	13	L....................67th St.	..	2	..	..	..	..	....	1413	50
	10	..	37	..	L....................Burnside	..	2	..	..	..	..	....	1418	0
	10	..	9:31	..	P.......................I. C.	3	..	..	..	..	..	....	52	..
	12	..	11	..	Exp...............Blue Island	..	4	..	..	..	..	....	1421	80
	..	13	..	14	Exp..................67th St.	..	2	..	..	..	..	....	1418	40
	..	18	..	19	Exp...............So. Chicago	..	6	..	..	..	..	....	1432	100
	..	18	..	19	Exp ....Flossmoor	..	3	..	..	..	..	....	1425	100
	..	19	..	23	L..................Woodlawn	..	6	..	..	..	..	....	1408	80
	21	..	20	..	L..................Woodlawn	..	2	..	..	..	..	....	1484	10
	2	..	6:47	..	P. ....C. C. C. & St. L.	4	..	3	..	..	..	....	171	..
	..	23	..	24	Exp ....Blue Island	..	5	..	..	..	..	....	1433	100
	..	27	..	27	P.......................I. C.	5	..	..	..	..	..	....	1045	..
	..	28	..	29	Exp...............So. Chicago	..	5	..	..	..	..	....	1405	90
	..	29	..	32	L....................Burnside	..	6	..	..	..	..	....	1438	80
	..	..	32	..	F....................... I. C.	..	..	..	17	..	..	....	903	..
	32	..	34	..	Exp...............So. Chicago	..	6	..	..	..	..	....	1406	60
	..	43	.	35	Exp..................67th St.	..	2	..	..	..	..	....	1435	90
	..	53	..	38	F.......................I. C.	..	..	..	34	..	36	....	634	..
	..	38	..	38	Exp................Flossmoor	..	6	..	..	..	..	....	1423	100
	..	39	..	41	L..................Woodlawn	..	5	..	..	..	..	....	1427	90
	..	..	41	..	Exp..................67th St.	..	2	..	..	..	..	....	1413	0
	..	41	..	7:39	F.......................M. C.	..	..	..	23	..	..	N. Y. C.	8269	..
	41	..	40	..	L..................Woodlawn	..	2	..	..	..	..	....	1402	5
	..	43	..	43	Exp...............So. Chicago	..	6	..	..	..	..	....	1416	110
	..	44	..	46	L....................Burnside	..	2	..	..	..	..	....	1414	70
	..	47	..	48	Exp...............Blue Island	..	6	..	..	..	..	....	1426	120
	..	..	49	..	Eng.........................	..	..	..	..	..	..	....	921	..
	..	49	..	51	L. ....Grand Crossing	..	5	..	..	..	..	....	1419	70
	..	51	..	52	Exp ....So. Chicago	..	5	..	..	..	..	....	1409	100
	51	..	6:01	..	P.......................M. C.	6	..	..	..	..	..	N. Y. C.	8458	..
	52	..	6:01	..	Exp ....Flossmoor	..	5	..	..	..	..	....	1440	70
	..	54	..	56	L...................Burnside	..	5	..	..	..	..	....	1407	30
	..	55	..	55	Exp. ....Homewood	..	6	..	..	..	..	....	1429	110
	..	59	..	59	L... ....Burnside	..	4	..	..	..	..	....	1417	60
	..	59	..	6:00	Exp. ....So. Chicago	..	6	..	..	..	..	....	1410	100
6 P. M.	01	..	01	..	L. .. ..Woodlawn	..	6	..	..	..	..	....	1408	5
	..	03	..	03	Exp..................Burnside	..	4	..	..	..	..	....	1406	110
	..	05	..	07	L.... ....Burnside	..	3	..	..	..	..	....	1421	80
	05	..	03	..	Exp ....67th St.	..	2	..	..	..	..	....	1435	0
	06	..	06	..	L.................Kensington	..	4	..	..	..	..	....	1422	5

	Schedule Time		Time Passed		Service	Number of Cars							Eng. No.	% Full	Remarks
	N.	S.	N.	S.		Coaches Bag. & Exp.	Suburban	Pullman	Box	Stock	All Other Cars				
	..	07	..	09	Exp. ... Blue Island	..	6	..	..	..	..	....	1412	100	
	..	08	..	17	P. ... I. C.	7	..	4	..	..	..	....	1035	..	
	..	09	..	11	L. ... Burnside	..	4	..	..	..	..	....	1497	70	
	..	11	..	14	Exp. ... Burnside	..	4	..	..	..	..	....	1404	110	
	12	..	12	..	Exp. ... So. Chicago	..	5	..	..	..	..	....	1437	25	
	..	..	15	..	Golf Special ...	..	2	..	..	..	..	....	1428	25	
	..	14	..	17	L. ... Burnside	..	4	..	..	..	..	....	1420	30	
	16	..	15	..	Exp ... Blue Island	..	5	..	..	..	..	....	1415	10	
	..	..	16	..	Work Train ...	..	..	..	1	..	3	....	1138	..	
	..	18	..	20	Exp. ... So. Chicago	..	6	..	..	..	..	....	1418	100	
	..	..	..	21	Eng. ...	..	..	..	..	..	..	....	903	..	
	..	19	..	21	L. ... Burnside	..	2	..	..	..	..	....	1434	25	
	21	..	20	..	L. ... Woodlawn	..	5	..	..	..	..	....	1427	5	
	..	23	..	24	Exp. ... Burnside	..	4	..	..	..	..	....	1402	80	
	..	24	..	27	L. ... Burnside	..	4	..	..	..	..	....	296	20	
	..	28	..	28	Exp ... Flossmoor	..	5	..	..	..	..	....	1440	100	
	..	29	..	30	L. ... Burnside	..	2	..	..	..	..	....	1413	20	
	31	..	40	..	P. ... C. C. & L.	6	..	..	..	..	..	....	1906	..	
	32	..	33	..	Exp. ... Blue Island	..	4	..	..	..	..	....	1436	20	
	..	38	..	40	Exp. ... So. Chicago	..	5	..	..	..	..	....	1437	110	
	..	39	..	41	L. ... Burnside	..	2	..	..	..	..	....	1435	50	
	41	..	40	..	L. ... So. Chicago	..	5	..	..	..	..	....	1405	20	
	..	47	..	8:03	F ... M. C.	..	..	..	37	..	..	N. Y. C.	8371	..	
	..	48	..	48	Exp. ... Blue Island	..	5	..	..	..	..	....	1415	80	
	..	49	..	50	L. ... Burnside	..	4	..	..	..	..	....	1428	20	
	..	52	..	8:21	F. ... I. C.	..	..	..	39	..	..	....	591	..	Refrigerator cars
	57	..	56	..	Exp. ... Harvey	..	5	..	..	..	..	....	1424	25	
	..	59	..	7:01	L. ... So. Chicago	..	4	..	..	..	..	....	1408	50	
7 P. M.	..	..	..	07	Eng. ...	..	..	..	..	..	..	....	171	..	
	..	10	..	8:52	F. ... I. C.	..	..	..	51	..	..	....	940	..	
	11	..	09	..	L. ... So. Chicago	..	5	..	..	..	..	....	1409	20	

	..	14	..	16	L ... Flossmoor	..	4	..	..	..	..	....	1436	80
	21	..	21	..	P ... I. C.	5	..	..	..	..	..	....	1046	..
	31	..	31	..	L ... Blue Island	..	4	..	..	..	..	....	1433	40
	37	..	37	..	Exp ... So. Chicago	..	6	..	..	..	..	....	1418	75
	43	..	8:05	..	P ... M. C.	2	..	4	..	..	..	N. Y. C.	8201	..
	..	44	..	47	L ... So. Chicago	..	4	..	..	..	..	....	1405	90
	..	..	44	..	... M. C.	..	..	..	1	..	..	N. Y. C.	8373	..
	46	..	45	..	L ... So. Chicago	..	5	..	..	..	..	....	1437	30
	47	..	45	..	Exp ... Flossmoor	..	6	..	..	..	..	....	1423	70
8 P. M.	01	..	02	..	L ... Blue Island	..	5	..	..	..	..	....	1426	50
	..	..	08	..	F ... M. C.	..	..	..	3	..	..	N. Y. C.	8261	..
	..	14	..	15	L ... Blue Island	..	4	..	..	..	..	....	1409	90
	16	..	16	..	L ... So. Chicago	..	4	..	..	..	..	....	1408	25
	21	..	20	..	P ... M. C.	12	..	..	..	..	..	N. Y. C.	7952	..
	33	..	31	..	P ... C. C. C. & St. L.	3	..	1	..	..	..	....	2007	..
	..	44	..	46	L ... So. Chicago	..	4	..	..	..	..	....	1433	80
	46	..	48	..	L ... Blue Island	..	6	..	..	..	..	....	1416	20
	..	..	..	57	F ... C C. & L.	..	..	..	14	..	1	....	215	..
9 P. M.	01	..	02	..	P ... M. C.	4	..	5	..	..	..	N. Y. C.	8450	..
	..	08	..	09	P ... C. C. C. & St. L.	5	..	3	..	..	..	....	1036	..
	..	14	..	19	L ... Flossmoor	..	4	..	..	..	..	....	1426	80
	..	14	..	14	P ... I. C.	6	..	1	..	..	..	....	2	..
	16	..	16	..	L ... So. Chicago	..	4	..	..	..	..	....	1405	30
	21	..	20	..	P ... I. C.	5	..	2	..	..	..	....	1048	..
	..	..	..	20	F ... I. C.	..	..	..	41	..	1	....	921	..
	..	39	..	38	P ... C. C. & L.	3	..	2	..	..	..	....	215	..
	..	43	..	44	P ... M. C.	10	..	..	..	..	..	N. Y. C.	7964	..
	..	44	..	46	L ... So. Chicago	..	4	..	..	..	..	....	1418	80
	46	..	49	..	L ... Flossmoor	..	4	..	..	..	..	....	1436	60
10 P.M.	..	..	08	..	F ... M. C.	..	..	..	36	..	2	N. Y. C.	8286	..
	..	09	..	10	P ... M. C.	4	..	4	..	..	..	N. Y. C.	8452	..
	..	14	..	17	L ... Blue Island	..	4	..	..	..	..	....	1408	80
	..	..	20	..	F ... I. C.	..	..	..	13	..	1	....	542	..
	16	..	15	..	L ... So. Chicago	..	4	..	..	..	..	....	1433	20
	..	23	..	25	P ... I. C.	5	..	4	..	..	..	....	1001	..
	..	..	..	31	F ... M. C.	..	..	..	49	..	1	N. Y. C.	8284	..
	..	..	34	..	F ... I. C.	..	..	..	63	..	14	....	631	..
	..	44	..	45	L ... So. Chicago	..	4	..	..	..	..	....	1412	80
	46	..	46	..	L ... Blue Island	..	4	..	..	..	..	....	1409	50
	..	..	59	..	Eng ...	..	..	..	..	..	..	....	897	..

	Schedule Time		Time Passed		Service	Number of Cars							Eng. No.	% Full	Remarks
	N.	S.	N.	S.		Coaches Bag. & Exp.	Suburban	Pullman	Box	Stock	All Other Cars				
11 P.M.															
	..	04	..	05	L...Kensington	..	4	..	..	..	..	....	1405	50	
	..	..	..	06	Eng...	..	..	..	..	..	..	....	542	..	
	13	..	00	..	F...I. C.	..	..	..	16	..	3	....	559	..	
	16	..	16	..	L...So. Chicago	..	4	..	..	..	..	....	1418	20	
	..	18	..	20	Exp...So. Chicago	..	6	..	..	..	..	....	1423	80	
	..	24	..	27	L...Woodlawn	..	4	..	..	..	..	....	1436	50	
	..	33	..	34	Exp...Flossmoor	..	6	..	..	..	..	....	1433	85	
	..	37	..	38	P...C. C. C. & St. L.	2	..	3	..	..	..	....	1046	..	
	..	39	..	45	L...So. Chicago	..	6	..	..	..	..	....	1437	30	
	..	..	..	45	Eng...	..	..	..	..	..	..	....	897	..	
	41	..	40	..	L...Flossmoor	..	4	..	..	..	..	....	1426	20	
	..	48	..	50	Exp...Blue Island	..	5	..	..	..	..	....	1409	80	
	..	..	..	50	F...M. C.	..	..	..	55	..	2	N. Y. C.	8283	..	

Abbreviations:—P., Passenger; L., Local Suburban; Exp., Express Surburban; Eng., Light Engine; F., Freight.

APPENDIX C

STATISTICS OF RAILROADS ENTERING CHICAGO:

Note:— The matter contained in Appendix C, is compiled from Poor's Manual, 1908, from the current report of the Illinois Warehouse and Grain Commission, and from the records of the county clerk of Cook County. Discrepancies in the mileage as given exist. No attempt has been made to correct the discrepancies as the entire and the Illinois mileages are given merely to show the relative importance of the roads and the relative importance to each road of its mileage within Illinois. For such purpose approximations are sufficient. The mileage within the city of Chicago is that returned by the railroads for purposes of taxation and is presumably accurate.

ROADS ENTERING DEARBORN STATION

	A. T. & S. F.	C. & W. I.	C. I. & L.	Erie	Gr'd Trunk	Wabash
Length of line operated in U. S. inclusive of trackage rights. Miles.....	10,520.46	27.27	599.76	2168.85	335.75	2,514.30
Mileage owned, Ill., main track	282.95	48.58	....	......	25.83	669.20
Mileage owned, Ill., 2d &c. main track..	77.13	81.37	....	......	25.83	80.70
Mileage owned, Ill., industrial tracks	11.86	......	....	......	......	4.94
Mileage owned, Ill., yards & sidings..	136.57	121.95	....	26.21	45.43	246.40
Mileage owned, Ill., total	508.51	251.90	....	26.21	97.09	1,001.24
Mileage owned, Chicago, main track..	7.37	25.16	....	......	8.52	4.92
Mileage owned, Chicago, 2d main track	5.91	25.16	....	......	8.52	4.92
Mileage owned, Chicago, yards&sidings	43.82	99.71	....	......	26.25	28.68
Mileage owned, Chicago, total........	57.10	150.03	None	None	43.29	38.52
Revenue from passenger service, Illinois.	$1,311,359	$105,724	$103,935	$82,590	$297,241	$2,544,787
Revenue per passenger per mile, Illinois	$0.01882	$0.00865	$0.020270	$0.01033	$0.01412	$0.01866
Passenger earnings per train mile, Ill.	$1.09140	$0.9993	$1.13552	$0.90608	$1.80780	$1.13321
Proportion to total earnings, Illinois ..	23.5%	95.8%	42%	24.6%	52.9%	31.1%
Freight revenue, Ill..	$4,132,566	......	$139,247	$251,021	$263,617	$5,575,225
Freight revenue, per ton mile, Illinois.	$0.01084	......	$0.00811	$0.00450	$0.00629	$0.00556
Freight earnings, per train mile, Illinois	$3.63253	......	$2.44362	$2,39000	$1.89262	$2.04031
Proportion to total earnings, Illinois..	74%	......	56.5%	75%	46.9%	68.3%
Total earnings per train mile, Illinois..	$2.43864	......	$1.66721	$1.64607	$1.85031	$1.65337
Total operating expenses per train mile, Illinois......	$1.57580	$1.09804	$1.23582	$1.29214	$1.28730	$1.26295

	A. T. & S. F.	C. & W. I.	C. I. & L.	Erie	Gr'd Trunk	Wabash
Proportion operating expenses to earnings from operation, Illinois	64.6%	......	74.1%	78.5%	......	76.3%
Passenger earnings per mile road.....	$4,517	......	$5,173	$4,132	$9,692	$3,419
Freight earnings per mile road	$14,236	......	$7,002	$12,577	$8,595	$7,490
Gross earnings per mile road	$19,215	$6,650	$12,373	$16,738	$18,322	$10,965
Average compensation of engineers	$4.87	$3.62	$3.73	$3.79	$4.05	$4.41
Average compensation of firemen	$2.89	$2.16	$2.16	$2.33	$2.25	$2.62
Total revenue train mileage	2,207,352	105,799	147,387	203,264	303,700	4,936,061
Total non-revenue train mileage	158,192	8,923	....	56,931	94,746	1,417,978
Coal consumed per mile in pounds, passenger	94.50	154.15	106.98	116.66	100.35	97.43
Coal consumed per mile in pounds, freight	206.64	......	188.88	201.48	160.39	175.18
Coal consumed per mile in pounds, switching	97.83	74.49	96.69	109.71	103.88	137.70
Coal consumed per mile in pounds, average	148.83	11.415	139.04	154.29	113.40	141.29
Average cost of coal at distributing point	$1.52	$1.88	$1.38	$1.80	1.80	$1.40

ROADS ENTERING UNION STATION

	C. & A.	C. B. & Q.	C.M. & St. P.	P.F.W. & C.	P.C.C.&S.L.
Length of line operated in United States inclusive of trackage rights, miles.....	970.33	8,875.07	7,410.82	482.28	1,471.52
Mileage owned, Illinois, main track..................	682.71	1,652.32	412.26	29.40	40.35
Mileage owned, Illinois, second and main track......	150.20	229.02	205.41	31.26	28.03
Mileage owned, Illinois, industrial track............	....	....	....	....	....
Milleage owned, Illinois, yards and sidings	260.95	750.70	308.82	74.54	79.11
Mileage owned, Illinois, total	1,093.86	2,632.04	926.49	140.70	147.49
Mileage owned, Chicago, main track	7.11	5.67	28.85	23.85	27.30
Mileage owned, Chicago, second main track..........	7.11	5.67	25.81	13.62	24.95
Mileage owned, Chicago, yards and sidings	32.60	80.17	103.01	89.96	74.23
Mileage owned, Chicago, total	46.82	91.51	157.67	123.43	126.48
Revenue from passenger service, Illinois	$3,332,027	$5,942,893	$2,448,655	$243,213	$190,662
Revenue per passenger per mile, Illinois	$0.02025	$0.01969	....	$0.01824	$0.01957
Passenger earnings per train mile, Illinois.............	$1.43101	$1.41572	$1.5917	$1.08832	$1.30787
Proportion to total earnings, Illinois	33.2%	26%	23%	21.6%	21%
Freight revenue, Illinois	$6,580,177	15,703,838	$8,144,773	$723,262	$591,879
Freight revenue, per ton mile, Illinois.............	$0.00568	$0.00647	....	$0.00630	$0.00619
Freight earnings, per train mile, Illinois.............	$2.80055	$3.00266	$3.31759	$2.51733	$2.43560
Proportion to total earnings, Illinois..................	65.7%	68.9%	76.7%	64.3%	65.4%
Total earnings per train mile Illinois..................	$2.15617	$2.43813	$2.34518	$2.19915	$2.33226
Total operating expenses per train mile, Illinois........	$1.29905	$1.89650	$1.28357	$4.36643	$2.79493
Pro. operating expenses to earnings from operation, Ill	60.2%	77.8%	54.7%	199%	119%
Pass. earnings per mile road..	$4,720	$3,536	$5,073	$7,853	$6,804
Freight earnings per mile road	$9,321	$9.344	$16,875	$23,354	$19,502
Gross earnings per mile road..	$14,181	$13,558	$22,000	$36,271	$29,816
Average compensation of engineers...................	$4.32	$4.11	$3.93	$3.66	$3.67
Average compensation of firemen....................	$2.61	$2.61	$2.49	$2.38	$2.21
Total revenue train mileage..	$4,642,975	9,345,805	4,527,660	510,789	387,996
Total non-revenue train mileage....................	4,226	17,566	....	47,221	27,400
Coal consumed per mile in pounds, passenger........	112.95	92.00	87.66	68.74	89.59
Coal consumed per mile in pounds, freight...........	209.72	206.00	125.67	155.57	179.56
Coal consumed per mile in pounds, switching........	107.30	101.00	91.47	116.41	106.82
Coal consumed per mile in pounds, average..........	149.77	144.00	108.07	115.21	135.40
Average cost of coal at distributing point...........	$1.01	$1.64	$2.13	$1.45	$1.20

ROADS ENTERING LA SALLE ST. STATION

	C. & E. I.	C. I. & S.	C.R.I.&P.	L.S.&M.S.	N.Y.C. &S.L.
Length of line operated in United States inclusive of trackage rights miles........	957.10	340.24	7,938.06	1,520.35	523.02
Mileage owned, Illinois, main track.....................	568.45	127.61	364.10	14.02	9.96
Mileage owned, Illinois, second &c. main track..............	141.46	5.33	206.41	8.69	1.37
Mileage owned, Illinois, industrial track..................	52.21				
Mileage owned, Illinois, yards and sidings................	310.89	59.12	300.04	73.85	31.30
Mileage owned, Illinois, total...	1073.01	142.06	870.55	96.56	42.63
Mileage owned, Chicago, main track.....................			18.42	5.71	8.70
Mileage owned, Chicago, second main track			17.52	5.71	
Mileage owned, Chicago, yards and sidings................			76.99	73.85	29.51
Mileage owned, Chicago, total...	None	None	112.93	85.27	38.21
Revenue from passenger service, Illinois....................	$1,716,441	$87,100	$2,898,022	$589,089	$58,895
Revenue per passenger, per mile, Illinois....................	$0.02074	$0.02047	$0.01844	$0.01859	$0.01190
Passenger earnings per train mile, Illinois...............	$1.03819	$0.53514	$1.19339	$1.62773	$1.32750
Proportion to total earnings, Illinois....................	17.3%	6.97%	29.9%	42.8%	43.1%
Freight revenue, Illinois........	$7,656,571	$1.040,412	$6,366,850	$560,485	$77,364
Freight revenue, per ton mile, Illinois.....................	$0.00480	$0.00625	$0.00841	$0.00782	$0.00914
Freight earnings, per train mile, Illinois....................	$2.77060	$2.31190	$3.95899	$8.79358	$1.88697
Proportion to total earnings, Illinois....................	77.3%	83.2%	65.7%	40.8%	56.7%
Total earnings per train mile, Illinois....................	$2.24213	$2.03931	$2.42917	$3.22716	$1.59791
Total operating expenses, per train mile, Illinois...........	$1.44650	$1.44802	$1.52010	$2.38667	$1.33626
Proportion operating expenses to earnings from operation, Illinois....................	64.5%	71%	63.5%	73.9%	83%
Passenger earnings per mile road	$3,020	$629	$7,955	$42,018	$3,123
Freight earnings per mile road..	$13,469	$6,953	$17,476	$39,977	$4,102
Gross earnings per mile road	$17,421	$8,352	$26,953	$97,976	$7,232
Average compensation of engineers	$5.04	$4.52	$4.02	$4.64	$4.11
Average compensation of firemen......................	$3.20	$2.79	$2.59	$2.83	$2.43
Total revenue train mileage.....	4,416,795	612,785	3,977,947	625,646	85,346
Total non-revenue train mileage	277,677	30,507	138,018		5,608
Coal consumed per mile in pounds, passenger..........	94.48	90.65	105.69	102.94	90.50
Coal consumed per mile in pounds, freight............	219.27	208.90	202.61	211.87	165.15
Coal consumed per mile in pounds, switching..........	147.62	114.20	118.48	120.51	94.50
Coal consumed per mile in pounds, average............	169.31	170.40	135.05	119.30	102.20
Average cost of coal at distributing point.................	$1.07	$1.94	$2.03	$1.69	$1.65

ROADS ENTERING CENTRAL STATION

	C. C. & L.	C.C.C.& St.L.	I. C.	M. C.	W. C.
Length of line operated in United States inclusive of trackage rights miles	254	2,629.39	4,377.44	1,746.46	1,022.74
Mileage owned, Illinois, main track....................	3.04	656.98	1,972.68	35.07	48.72
Mileage owned, Illinois, second and main track...........	....	76.64	469.93	6.07	20.11
Mileage owned, Illinois, industrial track.............	....	64.15	....	....	9.63
Mileage owned, Illinois, yards and sidings...............	.35	224.18	890.40	72.78	20.30
Mileage owned, Illinois, total.	3.39	1,021.95	3,333.01	113.92	98.76
Mileage owned, Chicago, main track....................	....	....	....	3.79	....
Mileage owned, Chicago, second main track	....	....	....	3.79	....
Mileage owned, Chicago, yards and sidings...............	....	....	....	42.60	....
Mileage owned, Chicago, total.	None	None	326*	50.18	None
Revenue from passenger service, Illinois..............	$3,418	$1,930,186	$7,196,868	$254,046	$287,192
Revenue per passenger per mile, Illinois...............	$0.01579	$0.01882	$0.01806	$0.02123	$0.01508
Passenger earnings per train mile, Illinois..............	$0.41260	$1.15768	$1.08754	$1.29216	$1.25566
Proportion to total earnings, Illinois..................	16.1%	30.6%	23.7%	20.8%	29.6%
Freight revenue, Illinois......	$17,777	$4,234,782	$18,005,742	$966,018	$672,647
Freight revenue, per ton mile, Illinois..................	$0.00669	$0.00600	$0.00522	$0.00644	$0.00826
Freight earnings, per train mile, Illinois	$1.83913	$2.48254	$2.16809	$2.86284	$3.02255
Proportion to total earnings, Illinois..................	83.7%	67.3%	59.4%	79.1%	68.5%
Total earnings per train mile, Illinois..................	$1.18312	$1.86679	$2.04889	$2.16404	....
Total operating expenses per train mile, Illinois.........	$1.25950	$1.40741	$1.27444	$1.78844	$1.05307
Proportion operating expenses earnings from operation, Illinois	107%	75.4%	622%	78.2%	48.4%
Passenger earnings per mile road....................	$656	$3,670	$3,622	$5,177	$4,087
Freight earnings per mile road	$3,314	$8,052	$9,061	$19,687	$9,250
Gross earnings per mile road...	$3,970	$11,963	$15,242	$24,864	$13,496
Average compensation of engineers....................	$4.88	$4.42	$4.54	$3.22	$3.98
Average compensation of firemen....................	$2.88	$2.67	$2.73	$1.99	$2.47
Total revenue train mileage...	17,950	3,370,067	14,782,252	533,742.	451,264
Total non-revenue train mileage....................	1,224	12,783	221,847	3,165	21,290
Coal consumed per mile in pounds, passenger	63.74	100.76	150.35	133.46	96.45
Coal consumed per mile in pounds, freight............	153.73	200.25	148.53	173.49	168.43
Coal consumed per mile in pounds, switching	106.21	112.43	147.65	73.54	105.33
Coal consumed per mile in pounds, average............	111.82	139.21	148.93	109.18	121.65
Average cost of coal at distributing point............	$1.76	$1.49	$1.27	$2.02	$1.85

* Including mileage outside of city limits, but over which a suburban service is maintained; such mileage being that over which electrification should logically be extended.

ROADS ENTERING GRAND CENTRAL DEPOT

	B. & O.	C. G. W.	Ch. Ter. Trf.	Pere Marq.
Length of line operated in United States inclusive of trackage rights, miles....	4,525.51	818.36	101.70	2,362.11
Mileage owned, Illinois, main track.....	382.74	153.12	73.99	....
Mileage owned, Illinois, 2d & c main track	11.49	6.08	46.13	....
Mileage owned, Illinois, industrial tracks	27.31	....	7.92	....
Mileage owned, Illinois, yards & sidings.	112.85	66.88	76.29	8.35
Mileage owned, Illinois, total...........	534.39	226.08	204.33	8.35
Mileage owned, Chicago, main track....	8.09	....	17.77	....
Mileage owned, Chicago, 2d main track..	8.05	....	16.19	....
Mileage owned, Chicago, yards & sidings.	25.67	16.01	50.77	....
Mileage owned, Chicago, total..........	41.81	16.01	84.73	None
Revenue from passenger service, Illinois.	$1,517,360	$505,240	$48,043	$59,526
Revenue per passenger per mile, Illinois............................	$0.02000	$0.02130	$0.00740	$0.02010
Passenger earnings per train mile, Illinois	$1.32788	$0.75231	....	$1.29329
Proportion to total earnings, Illinois....	28.4%	19.5%	2.9%	25.5%
Freight revenue, Illinois	$3,782,923	$2,051,003	$553,428	$167,773
Freight revenue, per ton mile, Illinois ...	$0.00682	$0.00684	....	$0.00819
Freight earnings, per train mile, Illinois..	$4.18917	$1.82766	....	$4.34994
Proportion to total earnings	61.5%	79%	34.2%	72.1%
Total earnings per train mile, Illinois....	$2.66920	$1.43871	$2.82208	$2.75022
Total operating expenses per train mile, Illinois.........................	$1.75771	$1.16432	$1.84674	$5.67682
Proportion operating expenses to earnings from operation, Illinois	65.8%	80.9%	65.4%	....
Passenger earnings per mile road.......	$3,791	$2,235	....	$1,445
Freight earnings per mile road..........	$9,452	$9,072	....	$4,071
Gross earnings per mile road..........	$13,336	$11,415	....	$5,646
Average compensation of engineers.....	$3.74	$4.05	$3.49	$4.44
Average compensation of firemen......	$2.07	$2.40	$2.21	$2.03
Total revenue train mileage...........	1,999,546	1,793,780	572,946	84,596
Total non-revenue train mileage.......	7,834	109,368	65,000	305
Coal consumed per mile in pounds, passenger...........................	101.20	108.03	91.10	98.92
Coal consumed per mile in pounds, freight	212.69	210.39	....	166.64
Coal consumed per mile in pounds, switching........................	114.45	109.74	214.00	131.67
Coal consumed per mile in pounds, average.............................	150.32	163.57	204.94	130.93
Average cost of coal at distributing point	$1.06	$2.23	$1.54	$1.75

C. & N. W. STATION

	C. & N. W.
Length of line operated in U. S. inclusive of trackage rights, miles	7,622.91
Mileage owned, Illinois, main track	718.88
Mileage owned, Illinois, second &c. main track	275.57
Mileage owned, Illinois, industrial track	....
Mileage owned, Illinois, yards and sidings	615.83
Mileage owned, Illinois, total	1,610.28
Mileage owned, Chicago, main track	34.82
Mileage owned, Chicago, second main track	34.07
Mileage owned, Chicago, yards and sidings	234.34
Mileage owned, Chicago, total	303.23
Revenue from passenger service, Illinois	$1,751,540
Revenue per passenger per mile, Illinois	$0.02000
Passenger earnings per train mile, Illinois	$1.10559
Proportion to total earnings, Illinois	28%
Freight revenue, Illinois	$4,477,080
Freight revenue per ton mile, Illinois	$0.00904
Freight earnings per train mile, Illinois	$2.46677
Proportion to total earnings, Illinois	71.6%
Total earnings per train mile, Illinois	$1.89904
Total operating expenses per train mile, Illinois	$1.23486
Proportion operating expenses to earnings from operation, Illinois	....
Passenger earnings per mile road	$2,557
Freight earnings per mile road	$6,536
Gross earnings per mile road	$9,122
Average compensation of engineers	$3.90
Average compensation of firemen	$2.40
Total revenue train mileage	3,290,582
Total non-revenue train mileage	335,462
Coal consumed per mile in pounds, passenger	118.08
Coal consumed per mile in pounds, freight	197.17
Coal consumed per mile in pounds, switching	101.98
Coal consumed per mile in pounds, average	135.26
Average cost of coal at distributing point	$1.86

TRANSFER AND TERMINAL RAILROADS NOT ENTERING PASSENGER STATIONS

	Belt Ry.	C. & C. R.	C. Jct.	U. S. Yd.	C. U. T.	C. & I. W.
Length of line operated in U. S. inclusive of trackage rights, miles	123.91	11.50	76.00	128.73	98.44	17.48
Mileage owned, Illinois, main track	....	1.25	23.86	8.76	7.00	10.73
Mileage owned, Illinois, second &c. main track	....	....	23.22	8.54	4.00	....
Mileage owned, Illinois, industrial tracks	....	......	1.63	....	....	....
Mileage owned, Illinois, yards and sidings	27.14	....	27.29	101.43	87.44	3.89
Mileage owned, Illinois, total	....	....	76.00	128.73	98.44	....
Mileage owned, Chicago, main track	19.09	2.19	3.15	8.77	....	.03
Mileage owned, Chicago, second main track	13.15	....	2.65	8.54	....	....
Mileage owned, Chicago, yards and sidings	66.36	.10	4.20	129.37	....	....
Mileage owned, Chicago, total	98.60	2.29	10.00	146.68	....	.03
Revenue from passenger service, Illinois	....	....	....		....	....
Revenue per passenger per mile, Illinois	....	....	....		....	....
Passenger earnings per train mile, Illinois	....	....	....		....	....
Proportion to total earnings, Illinois	....	......	....		....	....
Freight revenue, Illinois	$2,120,070	....	$861,818		....	$56,964
Freight revenue, per ton mile Illinois	....	....	$0.01330		....	$0.0512
Freight earnings per train mile, Illinois	$1.31398	....	$4.55711		....	....
Proportion to total earnings, Illinois	....	....	31.5%		....	....
Total earnings per train mile, Illinois	$1.31398	....	$1.46107		....	$50.67983
Total operating expenses per train mile, Illinois	$0.71108	....	$8.82956		....	....
Proportion operating expenses to earnings from operation, Illinois	54.1%	81.1%	610%		....	....
Passenger earnings per mile road	....	....	....		....	....
Freight earnings per mile road	....	....	$13,478		....	$5,309
Gross earnings per mile road	$44,812	$82,159	$42,771		....	$5,309
Average compensation of engineers	$3.72	$3.09	$3.65		....	$3.49
Average compensation of firemen	$2.38	$2.14	$2.27		....	$2.05
Total revenue train mileage	....	....	....		....	....
Total non-revenue train mileage	....	....	....		....	....
Coal consumed per mile in pounds, passenger	....	....	....		....	....
Coal consumed per mile in pounds, freight	....	....	....119.14...		....	...181.81
Coal consumed per mile in pounds, switching	175.27	70.75	77.01		....	202.79
Coal consumed per mile in pounds, average	175.27	70.75	79.99		....	195.85
Average cost of coal at distributing point	$1.62	....	$1.79		....	$2.00

TRANSFER AND TERMINAL RAILROADS NOT ENTERING PASSENGER STATIONS

	Ill. North.	Manf. Jct.	C. L. S. & E.	E. J. & E.	Ind. Har.
Length of line operated in U. S. inclusive of trackage rights, miles	21.62	6.32	590.08	236.87	213.94
Mileage owned, Illinois, main track	7.53	1.80	3.07	155.04	10.77
Mileage owned, Illinois, second &c. main track	....	....	2.71	24.68	10.77
Mileage owned, Illinois, industrial tracks	....	3.38	144.95	28.33	....
Mileage owned, Illinois, yards and sidings	6.76	1.14	....	102.03	6.49
Mileage owned, Illinois, total	14.29	6.32	....	310.08	....
Mileage owned, Chicago, main track	12.25	....	1.76	....	5.22
Mileage owned, Chicago, second main track	....	....	1.76	....	5.03
Mileage owned, Chicago, yards and sidings	....	1.16	3.20	12.53	....
Mileage owned, Chicago, total	12.25	1.16	6.72	12.53	10.25
Revenue from passenger service, Illinois	....	....	....	$685	....
Revenue per passenger per mile, Illinois	....	....	....	$0.02885	....
Passenger earnings per train mile, Illinois	....	....	....	$0.06062	....
Proportion to total earnings, Illinois	....	....	....	....	....
Freight revenue, Illinois	$67,117	....	$3,114,460	$2,023,091	$284,409
Freight revenue per ton mile, Illinois	$0.24732	....	$0.00882	$0.00525	$0.06313
Freight earnings per train mile, Illinois	$0.28249	....	$5.65022	$2.67703	....
Proportion to total earnings, Illinois	29%	....	80.5%	86.9%	....
Total earnings per train mile, Illinois	$0.98540	....	$7.01062	$3.07974	....
Total operating expenses per train mile, Illinois	....	....	$4.20248	$1.88945	....
Proportion operating expenses to earnings from operation, Illinois	....	....	59.9%	61.3%	176%
Passenger earnings per mile road	....	....	....	....	....
Freight earnings per mile road	$5,697	....	$1,258	$10,619	$5,119
Gross earnings per mile road	$19,876	....	$15,624	$12,216	$5,372
Average compensation of engineers	$3.57	$2.97	$3.69	$4.11	$3.76
Average compensation of firemen	$2.25	$2.97	$2.21	$2.47	$2.27
Total revenue train mileage	237,952	....	651,210	755,722	....
Total non-revenue train mileage	....	....	1,837	24,206	....
Coal consumed per mile in pounds, passenger	....	....	....	118.35	....
Coal consumed per mile in pounds, freight	....	....	228.45	165.91	....
Coal consumed per mile in pounds, switching	68.63	....	61.57	70.25	109.86
Coal consumed per mile in pounds, average	68.63	....	91.57	128.08	109.86
Average cost of coal at distributing point	$2.04	....	$1.22	$1.71	$2.08

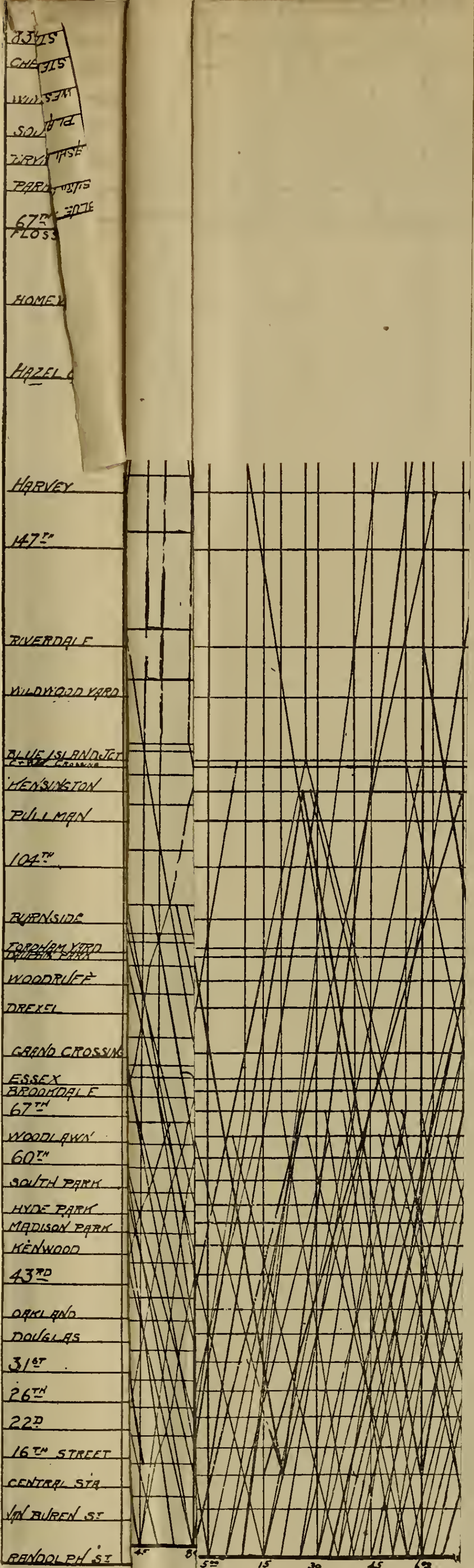

HARVEY
147TH
RIVERDALE
WILDWOOD YARD
BLUE ISLAND JCT.
KENSINGTON
PULLMAN
104TH
BURNSIDE
FORDHAM YARD
WOODRUFF
DREXEL
GRAND CROSSING
ESSEX
BROOKDALE
67TH
WOODLAWN
60TH
SOUTH PARK
HYDE PARK
MADISON PARK
KENWOOD
43RD
OAKLAND
DOUGLAS
31ST
26TH
22D
16TH STREET
CENTRAL STA
VAN BUREN ST
RANDOLPH ST
HOMEW
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PLATE A. ILLINOIS CENTRAL TERMINAL. SCHEDULED TRAIN CHART.

(MOVEMENT OVER TENANT ROADS' TRACKAGE AND OVER FREEPORT DIVISION NOT INCLUDED.)

PLATE B. ILLINOIS CENTRAL TERMINAL. 24 HOUR MOVEMENT AND POWER CURVES

A—Number of Trains on Line—Total.
B—Number of Trains on Line—North Bound.
C—Number of Trains on Line—South Bound.
D—Ton-miles per Minute—Total.
E—Ton-miles per Minute—North Bound Trains.
F—Ton-miles per Minute—South Bound Trains.
G—Load Curve—Kilowatts at Power House.